Original Article

Isolated Extra-Corporeal Coronary Perfusion Circuit for Use During Off-Pump Coronary Artery Bypass Grafting

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Keywords: myocardial revascularization, off-pump bypass, hemodynamics, cardiopulmonary bypass, heparin-coated circuitry

ABSTRACT

Cardiovascular surgery would not have developed into its present form without the heart–lung machine. In coronary artery bypass grafting (CABG), cardiopulmonary bypass allows accurate, all site, complete revascularization in a way convenient to the surgeon. The aim of this circuit is to find new ways to reduce invasiveness of CABG and to create new basis conditions for successful coronary bypass grafting on the beating heart. Manipulation of the heart compromises collateral coronary flow, especially to critically narrowed coronaries. This circuit standardizes our method for perfusing blood through the coronary bypass grafts with controlled positive pressure as each distal anastomosis is made, and it preserves collateral coronary flow, while facilitating construction of the remaining distal anastomoses.

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Article available at https://ject.edpsciences.org or https://doi.org/10.1051/ject/2000323162

INTRODUCTION

Off-pump coronary revascularizations have steadily increased in popularity recently allowing more elderly and high-risk patients to undergo surgical revascularization without the deleterious effects of cardiopulmonary bypass. Hemodynamic compromise can be a limiting factor in off-pump surgery. Manipulation of the heart during off-pump revascularization produces hemodynamic changes by means of compromised venous return, alterations in right ventricular geometry, and fluctuations in coronary blood flow. Ideally, off-pump revascularization should be performed with limited hemodynamic changes and uninterrupted blood flow by means of the newly constructed anastomoses. We describe an inexpensive, simple, and safe circuit that continuously perfuses each graft as soon as its distal anastomosis is completed. This system maintains tissue perfusion in the bypassed regions while other territories are being revascularized.

MATERIALS AND METHODS

DESCRIPTION OF THE CIRCUIT

The system consists of the following materials: A single roller pump head,[a] a 16-gauge femoral arterial catheter,[b] 4 feet of 3/16 polyvinyl chloride heparin-coated tubing,[c] a multiple perfusion set cardioplegia adapter,[d] a 3/16 connected bubble trap with manometer,[e] and an auto syringe infusion pump.[f] The arrangement and connection of these various components of the circuit are displayed in Figure 1.

OPERATION OF THE CIRCUIT

After induction of general anesthesia, the patient is prepped and draped in our usual fashion. A 16-gauge femoral arterial catheter is inserted using the Seldinger technique and connected to a pressure transducer to monitor blood pressure. After median-sternotomy, the internal mammary is harvested. Systemic heparinization is achieved keeping the activated clotting time (ACT) greater than 300 sec (at the standard dose of 1 mg/kg to 1.5 mg/kg heparin dosage for off-pump coronary surgical procedures.)

The femoral artery catheter is then connected to the 3/16 polyvinylchloride (PVC) heparin-coated tubing that is passed via the roller pump and the bubble trap to the multiport cardioplegia delivery system distally. Circuit line pressure is monitored by the Medtronic (DLP) manometer. The circuit crystalloid prime (NORMSOL) is approximately 50 mL. As soon as the circuit is connected to the femoral artery catheter, the prime can be flushed out at the multiport cardioplegia delivery system so as to provide blood, ready for graft perfusion. The first distal anastomosis is then performed (usually on the most easily accessible good target). One prong of the multiport cardioplegia system is then attached to it. The isolated extra-corporeal circuit is in place to provide continuous perfusion via the graft while other anastomoses are performed. As each distal anastomosis is made, the graft is connected to this system to allow for continuous perfusion of the corresponding myocardial segment. The line pressure in the circuit is continuously monitored. The autosyringe infusion system may be used to administer necessary medications (nitroglycerine, adenosine, etc).

DISCUSSION

Several techniques have been developed to preserve collateral coronary flow during off-pump coronary surgical procedures, including the use of Intra Aortic Balloon Pump (IABP), prioritizing grafting sequence, and intracoronary shunts. However, no satisfactory method of continuous perfusion of coronaries via the grafts exists to facilitate myocardial blood flow while the remaining distals and the proximal anastomoses are done (1).

Methods that rely on systemic blood pressure; that is, passive continuous perfusion systems, have potential disadvantages. First, perfusion via the system is completely dependent on the systemic pressure, which can be comprised by manipulation of the heart during positioning. This could cause decreased flow in a passive perfusion system, accelerating the already progressive downhill hemodynamic spiral. Second, kinking of the connection between the femoral catheter and the multiport system and lack of flow may go unrecognized if pressure is not monitored. In addition, it is difficult to infuse medications via this system without interrupting flow. Finally, application of the partial occluding clamp for proximal anastomosis construction will acutely increase myocardial afterload, thereby increasing myocardial oxygen demand.

A common method to circumvent the need for a passive continuous perfusion system is to perform the proximal anastomoses first. Thus, immediate perfusion of each compromised artery occurs upon completion of the distal anastomosis. However, difficulty in judging the length of the grafts for the distal anastomosis can be problematic, especially while manipulating the heart to perform the circumflex grafts (2).

Performance of each proximal immediately after each distal can also be done. However, this technique may be cumbersome and requires additional time, manipulation of the heart, and, most importantly, may lead to embolization or aortic damage by repeated application of the partial occluding clamp.

A continuous positive pressure circuit eliminates many of these potential risks. In addition, femoral inflow avoids aortic manipulation in cases of a calcified aorta where an alternate

[a] Stockert Instrumente, Munich, Germany
[b] Arrow International, Inc., Reading, PA
[c] Medtronic Cardiopulmonary Minneapolis , MN
[d] Cardioplegia Octopus–Medtronic DLP, Grand Rapids, MI
[e] Edwards Lifesciences LLC, Irvine, CA
[f] Model AS50, Baxter Healthcare Corp., Round Lake, IL

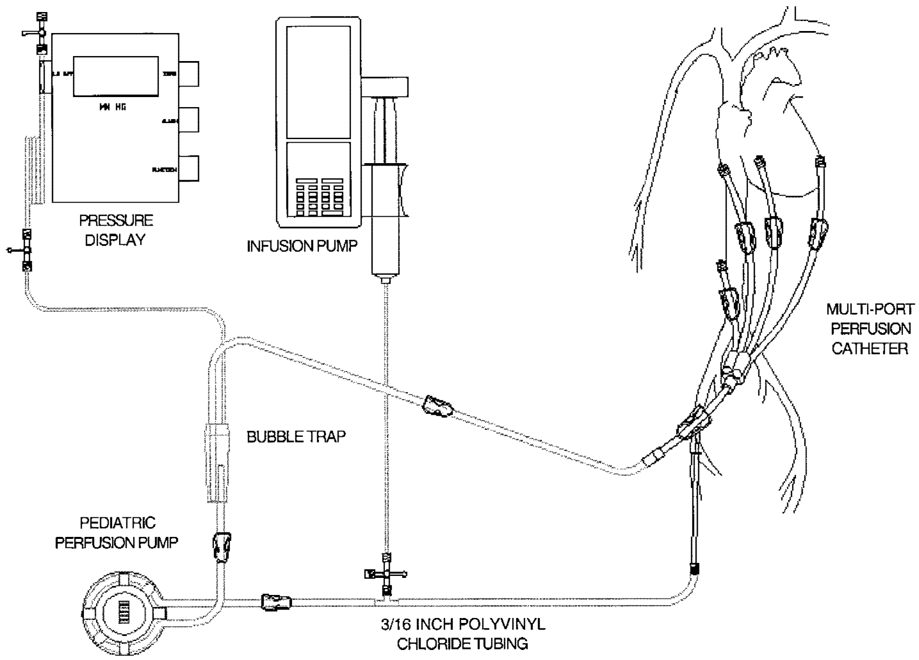

Figure 1: Diagram of isolated extra-corporeal circuit coronary perfusion circuit

site for proximal anastomosis, such as the innominate artery, descending aorta, subclavian /axillary artery or a T graft to the Left Internal Thoracic Artery or Right Internal Thoracic Artery (LITA/RITA) is being prepared. During preparation of this alternate site, the grafts are continuously perfused with our system. The usage of the Stockert Instrumente S3 heart–lung machine allows for pressure contol. This system was designed to allow the perfusionist to limit and control the pressure in the extracorporeal blood circuit. Depending on the operating mode selected, the control instrument monitors the pressure, and the controlled pump will slow down or stop as soon as the predetermined limit values are reached, and it activates audible and visual alarms.

The ability to use a coated circuit is another advantage of this circuit. Duraflo II (Edwards Lifesciences LLC, Irvine, CA)-coated materials use an ionic linkage, which is a simpler manufacturing process that still provides many of the hemostatic and anti-inflammatory advantages of heparin coating. Heparin itself has anticomplement activity. It is a well-known inhibitor of C3-convertase, which catalyzes the formation of C3a and C3b from C3. Heparin coating interferes with C3b binding to the circuit and renders this protein more available to systemic inactivators. By complement inhibition, a heparin-coated circuit can decrease the propensity for both white blood cell activation and degranulation.

Hemolysis does not occur from suction applied by the pump to the femoral arterial catheter as evidenced by clear urine postoperatively. No local complications from the femoral catheter have been noted.

This circuit provides the user with a simple, safe, and inexpensive extra-corporeal design to enhance unhurried and accurate construction of the distal and proximal anastomosis. Furthermore, an environment of hemodynamic stability can be attained by controlled positive pressure perfusion of grafts as they are constructed.

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