

**Original Article**

***Perfusion Technique for Perfusion-Assisted Direct Coronary Artery Bypass (PADCAB)***

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**ABSTRACT**

The role for the perfusionist has changed at many institutions that perform Off-Pump Coronary Artery Bypass (OPCAB). Surgeons at our hospitals have adapted a technique called Perfusion-Assisted Direct Coronary Bypass (PADCAB) (1). A simple circuit and pump have been devised for the perfusionist to deliver arterial blood to the myocardium immediately after the completion of the distal coronary anastomosis. Flow is controlled by a pressure-sensing servomechanism, and grafts are perfused at systemic or suprasystemic pressure. The pump is capable of delivering optional agents for myocardial vasodilatation, myocardial resuscitation, and for increasing myocardial performance.

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## INTRODUCTION

The evolution of surgery for coronary artery disease (CAD) has expanded rapidly in the past 30 years. "Beating heart surgery" has been performed in South America for many years as the only available option to surgeons constrained by economic conditions. Buffolo and Bennetti reported many "beating heart" cases from Brazil and Argentina, respectively. They demonstrated the possibility of off-pump coronary artery bypass surgery (OPCAB) and the ability to do it effectively at a lower cost to the patient (2, 3).

Recent clinical data suggest multiple benefits for patient outcomes when extracorporeal circulation is avoided during coronary artery bypass (CAB) surgery. These include: shorter hospital stay (3–5), less blood loss and transfusion (3, 5, 6), less systemic inflammatory response (4, 7), decreased neurologic postoperative complications (2), improved renal protection (8), and possible cost reduction (6, 7).

The long-term graft patency rate with OPCAB surgery remains to be determined. Some report short-term graft patency at 1 year to approximate closely that of on-pump coronary artery bypass (9).

Incomplete revascularization during OPCAB of patients with circumflex coronary artery disease has been associated with an increase in perioperative myocardial infarction, low cardiac output state, and early mortality (10). Improvements in exposure, retraction techniques, vascular control, and stabilizer devices for OPCAB have been successful toward total revascularization in many patients (11).

However, the effects of cumulative myocardial ischemia during multivessel OPCAB can result in high levels of pharmacological intervention and the possibility of hemodynamic collapse, which may require urgent cardiopulmonary bypass (CPB). Our institution has developed a technique for enhanced myocardial perfusion during OPCAB. We describe this technique, Perfusion-Assisted Direct Coronary Artery Bypass (PADCAB)(1).

## MATERIALS AND METHODS

Emory University Hospitals, Division of Cardiothoracic Surgery, in Atlanta, Georgia, have developed a technique to enhance myocardial perfusion during multivessel OPCAB. The Quest MPS<sup>™a</sup> pump has been adapted to deliver oxygenated blood from the aorta to the completed coronary bypass graft.

A standard Quest MPS<sup>™</sup> circuit is primed in the all crystalloid mode with normal saline and 5000 units of heparin. The additive cassette is filled with nitroglycerin (NTG) solution at a concentration of 10 µg/cc. The concentration is achieved by sterile dilution of 2 cc standard 200 µg/cc NTG solution with 38 cc of normal saline, for a final concentration of 10 µg/cc.

The blood reinfusion line is passed off from the sterile field. This is a standard Quest MPS<sup>™</sup> retrograde tubing with pressure transducer and monitoring line included. Once connected, these are primed, and the transducer is zeroed at the level of the heart.

The aortic blood access line consists of a sterile ¼ inch tubing, 40 inches in length, with one capped ¼ in. × ¼ in. connector and the other end a male luer-lock. The ¼ in. connector end is passed off from the sterile field and connected to the Quest MPS<sup>™</sup> blood access line. This line is retrograde primed by opening the Quest MPS<sup>™</sup> control door and slowly unlatching and opening the red pumping chamber cover slightly. The hydrostatic pressure from the saline prime bag fills the access line to the field. Once the line is primed, the blood access line into the Quest MPS<sup>™</sup> is clamped, and the red pumping chamber door is gently closed. To aid closing the door, the prime bag can be lowered to pump level to decrease the hydrostatic pressure to the pumping chambers.

With the patient fully heparinized (ACT > 400 sec), a 9-gauge DLP/Medtronic<sup>b</sup> cardioplegia cannula is inserted and sutured to the aorta at the lesser curvature. This site allows room for the partial occlusion clamp during the proximal anastomosis. The blood access line is then connected. The Quest MPS<sup>™</sup> blood ratio is selected to the all blood mode, and the temperature is set at 37°C. The reinfusion line is connected to a DLP/Medtronic<sup>b</sup> multiport perfusion Medusa, and the pressure monitoring line is connected to one of the multiport arms. The pump is turned on, and the circuit is primed with the patient's arterial blood, approximately 240 cc, and the crystalloid is discarded.

After the first saphenous vein or radial artery anastomosis is completed, the graft is connected to the Medusa by a standard 3-mm vein cannula. Blood flow is established with the Quest MPS<sup>™</sup> at a pressure of 100–125 mmHg. At this time, the surgeon can check the quality of the anastomosis for leaks with the stabilizer in place. The flow is recorded and maintained throughout the next anastomosis. As subsequent distal grafts are completed, the process is repeated, and perfusion is immediately restored to the target areas. As the proximals are completed, flow is decreased one graft at a time, while pressure is maintained. At the completion of all of the grafts, the Quest MPS<sup>™</sup> blood flow is terminated, and the protamine is administered. The residual pump blood is salvaged for reinfusion.

## RESULTS

Flow rates through the completed coronary anastomoses vary with size, quality, and distal run-off of the native coronary bed. Infusion rates for a single vessel have ranged from 30 cc/min to 160 cc/min. The pump perfusion pressures, measured from one arm of the Medusa, were maintained in a range of 100 to 125 mmHg.

<sup>a</sup> Quest Medical, Inc., Allen, TX

<sup>b</sup> Medtronic, Inc., Minneapolis, MN

Blood infused with a nitroglycerine concentration of 100  $\mu\text{g/L}$  increased blood flow, while pump perfusion pressure remained constant. An increase in flow of approximately 18% has been demonstrated at this NTG concentration (1).

Increases in the infusion pressure to the grafted area have a significant effect on flow rate. Increasing infusion pressure increases from 100 mmHg to 125 mmHg resulted in an average flow rate increase of 67% (1).

Blood flow rate increases as more vessels are completed and connected to the perfusion Medusa. Multivessel perfusion of the myocardium with the pumping device has yielded flows as high as 240 cc/min.

## COMMENTS

PADCAB has improved our ability to perform multivessel bypass grafts off pump with the goal of total revascularization and avoiding urgent CPB. In many instances, the perioperative ischemic EKG and hemodynamic pressures changes seen during OPCAB have been improved with the restoration of blood flow by the Quest MPS<sup>®</sup> pump. In addition, some patients with depressed myocardial function, observed intraoperatively by transesophageal echo, have shown regional wall motion improvement during this enhanced myocardial perfusion technique.

Since the initiation of PADCAB, the conversion rate to emergent CPB attributable to hemodynamic collapse has all but been eliminated. In many cases, inotropic support has been reduced while the myocardium is perfused with arterial blood at systemic or suprasystemic pressures. Also, the systemic effects of nitroglycerine can be avoided when used in small concentrations and administered directly to the myocardium via the pumping device's additive pouch. This may benefit the anesthesia technique of desired controlled hypertension before cardiac manipulation and during the distal anastomosis.

## DISCUSSION

As off-pump coronary artery bypass surgery (OPCAB) has become more popular, the perfusionist has mainly been serving the role as a resuscitator in the case of emergent CPB. Stabilizers, retractors, cardiac manipulation, vessel exposure, and occlusion can contribute to cardiac failure. Using this PADCAB technique, the perfusionist has been brought back into the realm of extracorporeal support, providing hemodynamic stability through enhanced myocardial perfusion. With immediate restoration of perfusion to the grafted myocardial regions, oxygen delivery to compromised tissue and collateral areas can be enhanced.

By providing blood flow to only the heart, we can indirectly support the patient during OPCAB without the detrimental effects of exposure to an entire cardiopulmonary bypass circuit. In most PADCAB cases, the total volume of blood

pumped directly in support of the heart equals approximately the volume pumped in 1–2 min during CPB. The blood exposure to foreign surfaces during PADCAB is minimized; thereby, decreasing the effects of complement activation, leukocyte activation, and platelet dysfunction.

PADCAB has demonstrated multiple benefits for the cardiac surgeon. Graft flows can be determined immediately upon completion of the anastomosis. In addition to perfusing the graft, the surgeon can pressure test the distal anastomosis for the detection of suture line leaks. This technique also allows the surgeon to perform vein graft sequencing in a more routine fashion and enables the left internal mammary artery (LIMA) anastomosis to be completed last. This avoids excessive manipulation of the heart while the LIMA pedicle is attached. The need for intraluminal shunts may be decreased with the use of PADCAB. This could minimize intraluminal arterial trauma that can be caused by these devices. In addition, blood flows through the shunts are directly dependent on the patient's arterial pressure. With a loss in the patient's mean perfusion pressure, the effectiveness of the shunt decreases. PADCAB allows maintenance of regional myocardial perfusion at systemic or suprasystemic pressures.

As Guyton et al. (1) have reported, the ability to perfuse the targeted myocardium at a higher controlled pressure may have a positive effect on myocardial performance. Experimentally, an observation known as the Gregg Effect demonstrated progressive improvements in performance with supranormal increases in myocardial blood flow (12). PADCAB can enhance myocardial perfusion by systemic or suprasystemic pressure to collateral regions. The increase in oxygen supply is an advantage over 'proximal-first' OPCAB strategies, because these techniques rely on blood delivered at systemic pressures (1).

In addition, the Quest MPS<sup>®</sup> pump design includes dual cassette additive pouches. This unique feature allows for minute administration of cardiac-enhancing drugs directly to the myocardium. Nitroglycerine has been the drug of choice for improved myocardial perfusion and coronary dilatation. No systemic blood pressure effects of NTG have been noted with additive infusion concentrations of NTG at 100  $\mu\text{g/L}$ . Future applications of this regional delivery of pharmacologic agents to the heart and other vital organs, by means of this technology, are being investigated.

The Quest MPS<sup>®</sup> has proved to be an ideal and safe device when used for this application. The passive filling of the pumping chambers avoids negative pressure in the aorta. The pressure-regulated flow servomechanism is extremely responsive and decreases the risk of overpressurization of the bypass graft. The heater/cooler unit is efficient, and the dual air detection devices, with their self-venting capability, provide an additional safety margin. No detrimental effects or complications have been associated with the use of the Quest MPS<sup>®</sup> during PADCAB.

All members of the cardiac team have readily embraced PADCAB. Patient management of volume delivery and ino-

tropic support provided by the anesthesiologist have been moderated. Surgeons have found the technique to be beneficial and easy to adapt. Moreover, the perfusionists have established an important role in providing improved patient care through modified extracorporeal circulation.

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