

# Off-Pump Coronary Artery Bypass Grafting with Use of the Octopus 2 Stabilization System

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## ABSTRACT

**Background:** The treatment of coronary artery disease has evolved rapidly over the last two decades. The gold standard of surgical revascularization, the on-pump coronary artery bypass graft, has been challenged by the development of percutaneous transluminal coronary angioplasty. Our experience with the alternative of the off-pump ("beating heart") coronary artery bypass (OPCAB) technique during a period of 18 months suggests that OPCAB avoids the complications of cardiopulmonary bypass and offers patients the benefit of long-term graft patency that greatly exceeds that of current endovascular technologies.

**Methods:** The early results of 126 OPCAB procedures performed through a medial sternotomy incision during a period of 18 months were evaluated. There were 80 male and 46 female patients, with a mean age of  $69 \pm 4.3$  years. Emergency cases and reoperations were not included. A total of 268 anastomoses were performed, with a mean number of 2.12 anastomoses per patient. Conduits used, with their percentage of use, were: left internal thoracic artery (LITA) (100%), right internal thoracic artery (11.1%), greater saphenous vein (84%), and radial artery (31%). In 72% of the cases, off-pump surgery was chosen because of patient risk factors such as atherosclerotic aortic disease, previous cerebrovascular accident or carotid artery disease, renal dysfunction, malignancy or poor left ventricular function.

**Results:** There was no operative mortality. One-month postoperative mortality was three patients (2.3%). Two died because of mesenteric ischemia, and the other death

was due to cardiac failure. Seventy-one patients had a control angiogram before discharge. The patency of LITA anastomosis was 100% while overall patency rate was 95%. In 43 patients for whom an angiogram could not be performed, a Thallium 201 stress test was performed three months postoperatively. Thirty-eight patients had a normal test while five patients showed signs of ischemia. These patients had a control angiogram: in four patients anastomoses were patent, but in one patient there was a severe narrowing of a venous anastomosis to the distal right coronary artery (RCA) which was corrected with angioplasty. In the whole series eight patients (6.3%) refused to have any control examination.

**Conclusions:** Our early results suggest that off-pump CABG with Octopus 2 (Medtronic, Inc., Minneapolis, MN) can be a good alternative in high risk patients who need multiple vessel revascularization.

## INTRODUCTION

The treatment of coronary artery disease (CAD) has evolved rapidly over the last two decades. The gold standard of surgical revascularization has been challenged by the development of percutaneous transluminal coronary angioplasty (PTCA). Factors like competition between cardiologists and cardiac surgeons for patients with coronary artery disease has again intensified with the emergence of beating heart coronary artery surgery (OPCAB), which avoids the complications of cardiopulmonary bypass (CPB) and offers the patient the benefit of long-term graft patency that greatly exceeds that of current endovascular technologies [Buffolo 1985, Benetti 1991]. CPB is one of cardiac surgery's most important developments and has made it possible for surgeons to perform coronary revascularization on a still and bloodless heart. However stopping the heart and temporarily replacing its functions with the heart-lung machine has risks associated with it [Elefteri-

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Table 1. Demographics and Risk Factors

Age	69 ± 4.3 years
Sex: M/F	80/46
Diabetes mellitus	21%
Hypertension	42%
Chronic obstructive lung disease	29%
LM	19%
LVEF < 25	20%
Renal insufficiency (Kr. >1.6)	16%
Cerebrovascular disease	33%
Malignancy	1.2%
Atherosclerotic aorta	32%
Age >75 years	27%
Peripheral vascular disease	8%

LM = left main disease, LVEF = left ventricle ejection fraction

ades 1997, Gu 1998]. Patients realize substantial benefits from undergoing beating heart coronary artery bypass grafting (CABG) [Buffolo 1985, Borst 1996, Buffolo 1997, Burfeind 1998, Calafiore 1998], among them:

- Shorter postoperative hospital stay
- Shorter ventilatory support period
- Less blood loss and fewer transfusions
- Less likelihood of low cardiac output
- Reduced systemic inflammatory response
- Fewer neurological complications

Importantly, research has indicated that beating heart CABG is not associated with increased rates of mortality or perioperative myocardial infarction [Elefteriades 1997, Gu 1998, Hart 1998]. This report describes our experience with the OPCAB technique during a period of 18 months.

## MATERIALS AND METHODS

During an 18-month period, 126 off-pump CABG procedures were performed via median sternotomy using the Octopus 2 stabilization system (Medtronic Inc., Minneapolis, MN). There were 80 male and 46 female patients, with a mean age was 69 ± 4.3 years. Emergency salvage cases and reoperations were excluded.

### Operative Protocol

All patients were premedicated with midazolam 0.07-0.1mg/kg IM. The preoperative evening all patients received a light enema. Anesthesia was induced with fentanyl and diprivan, and vecuronium was used for muscle relaxation. Anesthesia was maintained with fentanyl and diprivan perfusion with O<sub>2</sub> and N<sub>2</sub>O inhalation. With the induction, patients received diltiazem perfusion (1 mg/kg per hour) both for myocardial protection and heart rate reduction. Operating room temperature was maintained at 24-25°C. Initially, heparin (2 mg/kg) was administered and 50 mg was reapplied every hour. Preconditioning was not performed in

Table 2. Technical Data

Graft per patient	2.12 ± 0.8
Graft distribution	
Single	23%
Double	46%
Triple	30%
Quadruple	1%
Complete revascularization	86%
Conversion to CPB rate	3.1%

left anterior descending (LAD) and circumflex (Cx) anastomosis, nor in distal right coronary artery (RCA) lesions. Three to four left internal mammary artery (LIMA) stitches were placed in the pericardium to facilitate the anastomosis. The right pleural space was routinely opened for an easier Cx anastomosis. Every effort was made to achieve a complete revascularization. Complete revascularization was defined as bypassing three systems, namely LAD, RCA and Cx, with a critical stenosis having a vessel diameter of more than 1.25 mm. Using this criteria, complete revascularization could be achieved in 85% of the cases. Anastomosis for the proximal or middle RCA was avoided if possible when the vessel was not totally occluded, and the anastomosis was performed in the right descending posterior (RDP) or posterior lateral of the right coronary artery (PLRCA) branch. However, if a non-occluded RCA anastomosis was to be performed, atrial and ventricular pacemaker wires were routinely placed before the occlusion of the artery and an intra-coronary shunt was used. The LAD anastomosis was performed first in 91% of the patients. This was followed by the RCA and the Cx anastomoses. However in nine percent of patients with a critical LAD stenosis and occluded RCA, RCA anastomosis was performed first in order to graft collateralized vessels before collateralizing vessels. Collateralizing vessels were occluded only after collateralized vessels were bypassed. During anastomosis, vessels were occluded proximally only and a blower mister (Clear View™ Misted Blower, Medtronic, Inc., Minneapolis, MN) was used to facilitate the anastomosis. A total of 268 anastomoses were performed with a mean number of 2.12 anastomoses per patient. Demographic characteristics of patients are shown in Table 1 (⊙) and technical data are shown in Table 2 (⊙) and Table 3 (⊙). In 72% of the cases, OPCAB was chosen because of risk factors such as atherosclerotic aortic disease, previous cerebrovascular accident, carotid artery disease, renal disease, chronic lung disease and malignancy (Table 1, ⊙).

## RESULTS

There was no operative mortality. Early mortality was three patients (2.3%). Two of these patients died because of mesenteric ischemia. One patient who had to be converted to CPB under emergency conditions did poorly in the intensive care unit despite intra aortic balloon pump (IABP) sup-

Table 3. Vascular Conduits

LITA	100%
RITA	11.1%
LITA+RITA	32%
GSV	84%
Radial artery	31%
LIMA+RITA (free, Y graft)	6%

LITA = left internal thoracic artery; RITA = right internal thoracic artery; GSV = greater saphenous vein; LIMA = left internal mammary artery

port and died of multi-organ failure 10 days postoperatively. A total of four patients (3.1%) had to be converted to CPB, two for technical reasons and two for hemodynamic instability. Three patients with left ventricular ejection fraction (LVEF) < 25% received an IABP before the induction of anesthesia and OPCAB was performed with IABP support. Peri- and postoperative course was uneventful in these cases (Table 4, ☉ and Table 5, ☉).

Anastomosis were completed in 6 ± 3 minutes. Seventy-one patients in the OPCAB group had a control angiogram before discharge. Patency of left internal thoracic artery (LITA) anastomosis was 100% while overall patency was 95% (Table 6, ☉). In 43 patients for whom an angiogram could not be performed, a Thallium 201 stress test was performed three months postoperatively. Thirty-eight patients had a normal test while five showed signs of ischemia. The latter patients had a control angiogram: in four patients anastomoses were patent, but in one patient there was a severe narrowing of a venous anastomosis to the distal RCA which was corrected with PTCA. In the whole series, evaluation could not be done in eight patients because of patient refusal or logistical reasons.

**DISCUSSION**

Although the first coronary artery bypasses were performed without CPB, the great success stories of cardiac surgery were achieved by using CPB and cardioplegia [Benetti 1991, Buffolo 1997]. Economic reasons were the primary thrust for developing off-pump techniques, and

Table 4. Postoperative Morbidity

Reoperation (bleeding)	2%
Infection	0
Pulmonary complication	0
CVA	0
IABP	1%
MI	1.8%
Inotropic support	12%
Renal insufficiency	1%
Transfusion (units)	1.4 ± 0.8

CVA = cerebrovascular accident; IABP= intra aortic balloon pump

Table 5. Mortality (early)

Mesenteric ischemia	2
Cardiac causes	1
TOTAL	3 (2.3%)

this impetus did not gain popularity in industrialized countries not sharing the same problems. CPB also enabled surgeons all around the globe to practice and develop skills in a bloodless field with myocardial standstill. However, it was not long before publications on systemic effects of CPB began to appear in the medical literature. [Pfister 1992, Roach 1996]. Because of the increasing use of endovascular technologies and the advancing age of patients, surgical candidates are presenting with more and more co-morbidities. These co-morbidities can dramatically complicate procedures that use CPB, which itself can cause complications such as stroke, immunosuppression and systemic inflammatory response. These concerns, and the introduction of off-pump surgery via small incisions, rekindled interest in this alternative. The excellent results of Buffolo and Benetti encouraged the work of Pfister's group in Washington, and they reported their results in the Society of Thoracic Surgeons meeting in 1990. Although the report supported the safety and benefits of OPCAB, controversy remained [Pfister 1992].

The largest advance in beating heart CABG came with the introduction of mechanical stabilizers, intracoronary shunts, and blowers. Stabilizers have allowed more accurate surgery on the beating heart with traditional suture techniques [Jansen 1997, Burfeind 1998, Hoerstrup 1998, Jansen 1998, Rivetti 1998]. Mack and Calafiore have demonstrated that there was a significant improvement in graft patency rates after the use of stabilizers in OPCAB surgery [Burfeind 1998, Calafiore 1998]. These are comparable with patencies of grafts performed on-pump. Gundry and associates have reported a discouraging patency rate in OPCAB patients and have related this to the use of vascular snares (Gundry, personal communication). While some have disagreed with this report, use of vessel loops distally has largely been abandoned because of this concern. Although we have not encountered this in our series, we use vessel loops (Surgiloop, Ethicon Endo-Surgery, Inc., Cincinnati, OH) only proximally and control distal bleeding with a blower mister (Clear View™ Misted Blower, Medtronic, Inc., Minneapolis, MN). Slowing the heart with

Table 6. Control Angiography

N=71 (56%)	
LIMA patency	100%
RIMA patency	100%
Overall patency	95%

LIMA = left internal mammary artery; RIMA = right internal mammary artery

diltiazem perfusion, filling the heart and using vasopressors when necessary are the common maneuvers performed by the anesthesiologist [Nierich 1998, Peterson 1997].

Although clinical studies comparing outcomes of OPCAB and CABG with CPB have reported that patients undergoing beating heart CABG may benefit in many ways. Major benefits in terms of atrial fibrillation, cost savings, and mortality could not be shown [Calafiore 1998]. Probably the major reason for this was that in most of these studies no comparison was made between patients with similar high risks who were underwent surgery off- and on-pump. This was the same in our study, in which 72% of OPCAB patients underwent this procedure because of high risk factors. CPB-related problems such as microemboli with neuropsychological morbidity, coagulation disorders, immunosuppression and systemic inflammatory response with pulmonary, renal and gastrointestinal effects increase the risk for all patients to the point of excluding some patients as surgical candidates.

The indication for the procedure in our experience can be any patient undergoing coronary artery revascularization, depending on the experience of the surgeon [Calafiore 1998, Stanbridge 1998]. However, the indication should be tailored according to the needs of the patient. In the beginning of our experience, OPCAB was reserved mainly for patients with multiple risk factors that would make an operation on CPB hazardous. These include older patients (> 75 years), patients with cerebro-vascular, renal, or respiratory problems, and patients with an extremely atherosclerotic aorta. Other candidates include patients with immunosuppression or those who have a malignancy. The benefits of avoiding CPB in these patients have been established. Revascularization of the most important target vessel or vessels (culprit lesions) should be the aim. Incomplete revascularization may be accepted for the sake of short-term recovery, and these patients can undergo PTCA procedures for their ungrafted vessels later, thus receiving the so called "hybrid therapy."

The second group for whom the procedure may be indicated are the patients with no or minimal risk factors for CABG operations. For this group, incomplete revascularization is unacceptable. No vessel planned preoperatively to be bypassed should be skipped. If complete revascularization cannot be accomplished with OPCAB, there should be no hesitation to convert the operation since this represents a major benefit for the patient. It has been shown that elective conversion of an OPCAB operation does not increase morbidity, while urgent conversion due to hemodynamic instability can be hazardous [Stanbridge 1998].

Another group of patients who are not very good candidates for OPCAB are those with dilated or hypertrophied ventricles. In this group of patients, exposure of the lateral wall can be extremely difficult and most of the time these patients do not tolerate extensive manipulations. Also, patients with low left ventricle ejection fractions (LVEF < 25%) or arrhythmias, and patients on chronic atrial fibrillation, are not in our view good candidates for this procedure.

We were able to perform control coronary angiography in 56% of OPCAB patients. For logistical reasons this was

done before the patient was discharged. The overall patency was 95%, and now we do not routinely catheterize our patients. However, we do believe that a Doppler examination should be performed in the operating room. To date, we have performed 201 OPCAB procedures in our Institute. Our results suggest that this procedure can be a good alternative to on-pump coronary artery bypass graft. Stabilizers and other high-tech equipment are important tools for this procedure, enabling the surgeon to perform a perfect anastomosis. However, the surgeon's decision-making remains the most important factor contributing to the outcome of the operation. A good indication, solid judgment, perfect anastomosis, complete revascularization, knowing where to stop or convert, patience and experience remain the most important assets for a good result.

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