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Multivessel Off-Pump Coronary Artery Bypass: Analysis of 4953 Cases

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ABSTRACT

Background: To avoid the harmful effects of cardiopulmonary bypass (CPB), cardiac surgeons are using off-pump coronary artery bypass (OPCAB) as an effective alternative to conventional coronary artery bypass grafting (CABG). In the present study, we analyze our results with OPCAB in patients with multivessel coronary artery disease and compare them with those achieved in patients who underwent operations on CPB.

Methods: Between January 1997 and April 2002, 4953 patients underwent CABG without CPB (OPCAB group). These patients were compared with 7133 patients who underwent conventional on-pump CABG (CCAB group) during the same period. All patients were operated on through a median sternotomy. The Octopus was used as the mechanical stabilizer, and intracoronary shunts were used in most patients. Transesophageal echocardiography was used in all patients, and epiaortic scanning was used in selected patients.

Results: The mean patient age was 59 ± 8.9 years in the OPCAB group and 57.4 ± 8.9 years in the CCAB group (P < .001). There were more women in the OPCAB group (11.7% versus 10.4%; P = .023), and 2.8% of the patients required conversion to CPB. The mean numbers of grafts were 3.0 ± 0.7 and 3.2 ± 0.8 in the OPCAB and the CCAB groups, respectively (P < .001). More patients in the CCAB group received grafts to the circumflex territory. Intubation times (19 ± 4 hours versus 25 ± 6 hours; P < .001), blood losses (350 ± 41 mL versus 598 ± 74 mL; P < .001), requirements for blood and blood products (30.8% versus 45.3%; P < .001), the frequency of reopening for bleeding (0.6% versus 2.8%; P < .001), requirements for postoperative intra-aortic balloon pump (1.3% versus 2.6%; P < .001), the frequency of atrial fibrillation (10.9% versus 18.9%; P < .001), and stroke frequency (0.8% versus 1.2%; P = .043) were all significantly lower in the OPCAB group. The mortality rate was 0.97% and 1.86% in the OPCAB and the CCAB groups, respectively (P < .001). Intensive care unit stays (23 ± 6 hours versus 34 ± 8 hours; P < .001) and hospital stays (5 ± 2 days versus 8 ± 3 days; P < .001) were significantly shorter in the OPCAB group.

Conclusion: OPCAB is a safe and effective procedure for patients with multivessel coronary artery disease and is associated with reduced morbidity and mortality. However, large randomized studies with long-term follow-up may show the real benefits of OPCAB compared with CABG on CPB.

INTRODUCTION

Cardiopulmonary bypass (CPB) has long been recognized as one of the major causes of systemic inflammatory response, which may contribute to postoperative complications and even multiorgan dysfunction [Wan 1997]. The mortality and significant morbidity of coronary artery bypass grafting (CABG) is largely attributed to the use of CPB, global cardiac arrest, hypothermia, median sternotomy, and manipulation of the aorta. In the last few years, off-pump coronary artery bypass (OPCAB) grafting has emerged as an effective alternative technique for allowing coronary revascularization without the use of CPB [Ascione 1999, Arom 2000a, Arom 2000b]. OPCAB has been shown to be associated with decreased postoperative morbidity, shorter hospital stay, reduced cost [Calafiore 1999, Ascione 1999], and reduced operative mortality in some studies [Calafiore 2001, Arom 2000b].

Early experience with OPCAB was confined to easily accessible anterior vessels, and OPCAB was not recommended for circumflex or lateral marginal grafting [Reichenspurner 1998]. Recent developments in the techniques of coronary artery exposure and myocardial stabilization have allowed the use of OPCAB in multivessel disease and have yielded encouraging results [Izzat 1997, Hernandez 2001].

We started CABG without CPB in 1995, initially as minimally invasive direct coronary artery bypass with anastomosis of the left internal thoracic artery to the left anterior descending artery (LAD) via an anterior thoracotomy. We slowly expanded the use of CABG without CPB to patients with double-vessel disease, mainly the LAD and the right coronary artery. As our experience increased, we extended OPCAB to patients with multivessel disease. Currently, all

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patients requiring isolated coronary artery bypass are considered for OPCAB. In the present study, we analyzed our results with OPCAB in patients with multivessel disease and compared these results with those of patients who underwent operations on CPB.

MATERIALS AND METHODS

Between January 1997 and April 2002, 12,086 patients with double- or triple-vessel disease underwent isolated CABG at our institute. These patients were divided into 2 groups: (a) patients who were operated on without CPB, the OPCAB group; and (b) patients who underwent operations with CPB, the conventional coronary artery bypass (CCAB) group. Preoperative, intraoperative, and postoperative data for these patients were entered prospectively into a database and analyzed retrospectively.

Anesthesia and Monitoring

Patients were premedicated with morphine (0.1 mg/kg) and lorazepam (2-4 mg). Induction was achieved with midazolam (15-20 (μg/kg) and fentanyl (10-100 (μg/kg). Muscle relaxation was achieved with vecuronium bromide (0.10-15 mg/kg). Anesthesia was maintained with oxygen, air, and incremental doses of midazolam and fentanyl. All patients had a radial artery cannula and a pulmonary artery catheter for the monitoring of mean arterial pressure, central venous pressure, mean pulmonary arterial pressure, pulmonary capillary wedge pressure, cardiac index, stroke volume, and systemic vascular resistance. Femoral artery cannulation was performed in patients with poor ventricular function (left ventricular ejection fraction <30%) in the event that urgent institution of an intra-aortic balloon pump was required. A combination of lead II and V_5 was continuously displayed and used for ST-segment analysis. Arterial blood gases and activated clotting time were monitored every 30 minutes. The patient's temperature, which was constantly monitored by a properly placed nasal temperature probe, was maintained close to 36°C with a water-heated mattress, a fluid warmer, and an ambient operating room temperature of >20°C.

Intraoperative transesophageal echocardiography monitoring was used in all patients to assess global and regional left ventricular function, mitral regurgitation, right ventricular function, tricuspid regurgitation, and the thoracic aorta. Epiaortic scanning was performed in selected patients who showed evidence of atherosclerosis by transesophageal echocardiography or on palpation of the aorta.

Technique of OPCAB

All patients were operated on through a median sternotomy. The internal thoracic artery, the radial artery, and the saphenous vein were harvested as appropriate with standard techniques. The patient was heparinized with a dose of 2 mg/kg body weight, and the activated clotting time was kept at >300 seconds. Coronary arteries were stabilized with the Octopus 2, Octopus 2+, and Octopus 3 (Octopus Tissue Stabilization System; Medtronic, Minneapolis, MN, USA). Intracoronary shunts (Anastaflo intravascular shunt; Baxter, Irvine, CA, USA) of different sizes (1.5 mm, 2 mm, and 2.5 mm) were used in most patients to maintain coronary flow, thereby reducing myocardial ischemia and at the same time minimizing bleeding from the coronary arteriotomy. An oxygen blower was used to achieve a clear operating field.

The LAD was usually grafted first, and grafting was achieved without much displacement of the heart and without much hemodynamic compromise. Occluded coronary arteries were usually revascularized before stenosed ones. The proximal anastomosis was performed before performing the next distal anastomosis. The guiding principle was that more cardiac displacement was tolerated as revascularization became increasingly complete. However, the sequence of grafting was individualized for each patient and depended on various factors, including hemodynamic stability after tilting the heart and the severity of the stenosis. Distal anastomoses were performed with continuous 7-0 or 8-0 polypropylene (Prolene) monofilament suture. Proximal anastomoses were performed with 6-0 continuous Prolene suture. Before placing the side-biting clamp for the proximal anastomosis, the systemic blood pressure was lowered, either by the anesthesiologist using antihypertensive agents or by the surgeon using inflow occlusion.

For exposure of the obtuse marginal vessel, 2 or 3 deep pericardial traction sutures were positioned between the left superior pulmonary vein and the inferior vena cava. The other measures that were applied for exposure and maintenance of better hemodynamics included extensive right pleurotomy, deep vertical right pericardiotomy, and hemisternum elevation. Recently, verticalization of heart has been obtained with the Starfish Heart Positioner (Medtronic), especially in patients with dilated hearts and poor ventricular function.

After the procedure, heparin therapy was reversed with protamine sulfate in a 1:1 ratio.

Technique of Coronary Artery Bypass on CPB

Standard CPB was established with ascending aortic and 2-stage venous cannulation. The conduits were harvested with standard techniques. Most patients were operated on under cardioplegic arrest. Myocardial protection was achieved with warm blood cardioplegia, and cardioplegia was repeated after every distal anastomosis. Some patients underwent operations on an empty beating heart without cross-clamping.

Postoperative Management

After surgery, all patients were admitted to the intensive care unit (ICU). A standard postoperative management protocol was followed. Patients were extubated in the ICU as soon as possible, depending on the patient's hemodynamic stability. Antibiotic administration was continued until the patient had central lines or chest drains (normally 24-48 hours).

Definitions

Perioperative myocardial infarction was defined as the development of new q waves on the postoperative electrocardiogram or loss of R wave progression, a new left bundle-branch block or new ST-and T-wave changes in association with an increase in creatine kinase level of >40 U/L or a creatine kinase–MB to creatine kinase ratio of greater than 5%.

Table 1. Demographic Profile*

Variables	OPCAB Group (n = 4953)	CCAB Group (n = 7133)	P
Age, y	59.0 ± 8.9	57.4 ± 8.9	<.001
Age >70 y, n (%)	505 (10.2)	454 (6.4)	<.001
Male, n (%)	4372 (88.3)	6390 (89.6)	.023
Female, n (%)	581 (11.7)	743 (10.4)	.023
NIDDM, n (%)	1783 (36.0)	2554 (35.8)	.843
IDDM, n (%)	74 (1.5)	135 (1.9)	.114
Hypertension, n (%)	2575 (52.0)	3416 (47.9)	<.001
Smokers, n (%)	1188 (24.0)	1730 (24.3)	.751
COPD, n (%)	406 (8.2)	456 (6.4)	<.001
History of CVA, n (%)	104 (2.1)	121 (1.7)	.122
Previous MI, n (%)	2501 (50.5)	3481 (48.8)	.070
Recent MI, n (%)	138 (2.8)	221 (3.1)	.348
NYHA class III or IV, n (%)	624 (12.6)	842 (11.8)	.198
PVD, n (%)	223 (4.5)	328 (4.6)	.838
Obesity, n (%)	574 (11.6)	913 (12.8)	.049
Unstable angina, n (%)	1387 (28.0)	1991 (27.9)	.929
Redo CABG, n (%)	76 (1.5)	133 (1.9)	.097
Urgent surgery, n (%)	442 (8.9)	620 (8.7)	.682
Preoperative IABP, n (%)	124 (2.5)	192 (2.7)	.562
CHF, n (%)	317 (6.4)	421 (5.9)	.278

*Data are presented as the mean ± SD where appropriate. OPCAB indicates off-pump coronary artery bypass; CCAB, conventional coronary artery bypass; NIDDM, non–insulin-dependent diabetes mellitus; IDDM, insulin-dependent diabetes mellitus; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; MI, myocardial infarction; NYHA, New York Heart Association; PVD, peripheral vascular disease; CABG, coronary artery bypass grafting; IABP, intra-aortic balloon pump; CHF, congestive heart failure.

Prolonged ventilation was defined as ventilation for more than 48 hours. Mediastinitis was defined as a mediastinal collection with positive culture results. Acute renal failure was defined as a requirement for peritoneal dialysis or hemodialysis. Total operative time was defined as the time from skin incision to the closure of the skin. Neurologic complications were defined as transient ischemic attack (resolving completely within 24 hours) or stroke (cerebral dysfunction lasting >24 hours). Cerebrovascular accident was diagnosed by a neurologist and confirmed by brain scan.

Urgent surgery was defined as surgery within 24 hours of an angiogram. The surgery was considered as emergency surgery when the patient was shifted directly to the operating theater from the catheterization laboratory or when the surgery was required within a few hours of admission or performing the angiography.

Statistical Analysis

Data are reported as the mean ± SD. The χ^2 test and the Fisher exact test were used to compare categorical variables. Unpaired Student *t* tests were used to compare intergroup means. A *P* value of less than .05 was accepted as statistically significant. Variables that were not normally distributed were evaluated with the Mann-Whitney test.

RESULTS

There were 4953 patients in the OPCAB group and 7133 patients in the CCAB group. The demographic profiles of the two groups of patients are shown in Table 1. The mean age of the patients in the OPCAB group was higher, and there were more women in this group. The comorbidities were comparable for the two groups except for higher frequencies of hypertension and chronic obstructive pulmonary disease in the OPCAB group and a higher frequency of obesity in the CCAB group. Approximately half of the patients in both groups had previously had one or more myocardial infarctions.

One hundred thirty-eight patients (2.8%) required conversion to CABG with CPB. These patients were included in the OPCAB group for the analysis.

Table 2 summarizes the findings of coronary angiography. The incidence of patients with triple-vessel disease was higher in the CCAB group, and more patients in the CCAB group had left main stenosis. The incidence of patients with triple-vessel disease in the OPCAB group has been increasing since 1997, and all patients with triple-vessel disease currently are candidates for OPCAB (Figure 1). There has been no significant difference for the last 2 years in the incidence of triple-vessel disease in the two groups of patients (Figure 1). In addition, all patients with left main stenosis are presently considered for OPCAB. Left ventricular function was comparable for the two groups; approximately one third of the patients in both groups had compromised left ventricular function (left ventricular ejection fraction ≤40%).

The intraoperative details of the patients are shown in Table 3. Patients in the CCAB group received more grafts than the patients in the OPCAB group. The LAD territory was revascularized in almost all patients in both groups (OPCAB, 99.4%; CCAB, 99.6%). There was no significant difference between the two groups in the number of grafts to the right coronary artery territory, but the number of patients who received grafts to the circumflex territory was significantly smaller in the OPCAB group. There were no differences in the types of conduits used in the two groups of patients. Most patients in both groups (OPCAB, 98.6%; CCAB, 98.2%) received the left internal mammary artery.

Table 2. Coronary Angiography Findings*

Variables	OPCAB Group (n = 4953), n (%)	CCAB Group (n = 7133), n (%)	P
Double-vessel disease	1295 (26.1)	1153 (16.2)	<.001
Triple-vessel disease	3658 (73.9)	5980 (83.8)	<.001
Left main stenosis	425 (8.6)	743 (10.4)	<.001
Left ventricular ejection fraction			
>50%	1912 (38.6)	2691 (37.7)	.329
41%-50%	1543 (31.2)	2213 (31.0)	.897
31%-40%	960 (19.4)	1437 (20.1)	.301
≤30%	538 (10.9)	792 (11.1)	.699

*OPCAB indicates off-pump coronary artery bypass; CCAB, conventional coronary artery bypass.

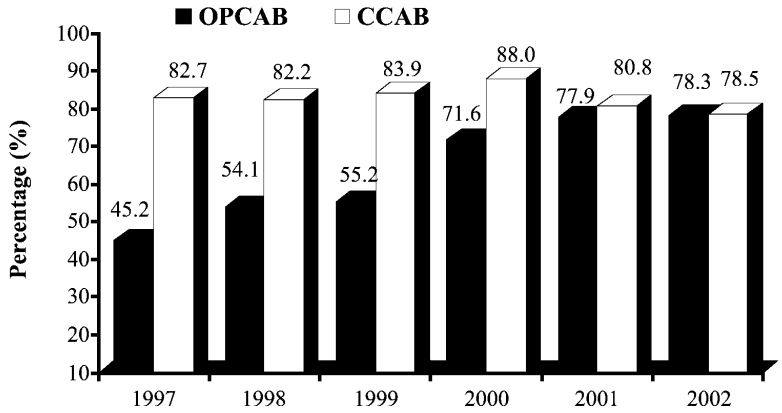

Figure 1. Percentages of patients with triple-vessel disease undergoing off-pump coronary artery bypass (OPCAB) and conventional coronary artery bypass (CCAB) between July 1997 and April 2002.

Two hundred thirty-six patients (3.3%) in the CCAB group underwent operations on the beating heart (without cross-clamping and cardioplegia). The rest of the patients underwent operations with cross-clamping and cardioplegia. The incidence of patients requiring inotropes intraoperatively was higher in the OPCAB group. The total operating time was significantly lower in OPCAB group.

The postoperative results are shown in Table 4. Patients in the OPCAB group were extubated earlier than the CCAB group. The levels of blood loss were significantly lower in the OPCAB group, and significantly fewer patients in the OPCAB group required blood or blood product transfusion. There were no statistically significant differences between the two groups of patients in the rates of perioperative myocardial infarction, requirements for inotropes in the ICU, renal dysfunction, and sternal complications. Significantly fewer patients in the OPCAB group required an intra-aortic balloon pump in the ICU, and fewer patients in that group underwent exploration for bleeding. The incidence of postoperative atrial fibrillation was significantly lower in the OPCAB group, and fewer patients in this group required prolonged ventilation. The incidence of stroke was also lower in the OPCAB group. The 30-day mortality rate was significantly lower in the OPCAB group than in the CCAB group. The mean stays in the ICU and the hospital were also significantly shorter in the OPCAB group.

DISCUSSION

CABG without CPB was introduced as early as 1967 [Kolessov 1967], but CABG on CPB became dominant with the technologic advances in CPB and cardioplegic arrest, which provided a quiet and bloodless field. The resurgence in beating heart surgery began in the early 1990s, although only a few surgeons practiced it at the time [Buffolo 1990, Benetti 1991]. Recently, OPCAB has gained large acceptance with its good short-term results [Arom 2000a, Arom 2000b, Ascione 1999]. Initial experience with OPCAB was limited to single- or double-vessel disease [Arom 2000a, Puskas 1998]. With the availability of better stabilization techniques and surgeons' increasing experience, OPCAB is being used for patients with multivessel disease [Hernandez 2001, Roy 2001, Mack 2002]. In the present study, we have analyzed our experience with OPCAB in patients with multivessel coronary artery disease.

In our study, morbidity in patients who underwent OPCAB was found to be lower than in patients who underwent CABG on CPB. Numerous other studies have shown a trend toward lower rates of morbidity and mortality and shorter lengths of hospital stay after OPCAB [Calafiore 1999,

Table 3. Intraoperative Variables*

Variables	OPCAB Group (n = 4953)	CCAB Group (n = 7133)	*P*
No. of grafts	3.0 ± 0.7	3.2 ± 0.8	<.001
CPB time, min	—	84 ± 12	—
ACC time, min	—	36 ± 7	—
CPB with ACC, n (%)	—	6897 (96.7)	—
CPB without ACC, n (%)	—	236 (3.3)	—
Total operating time, min	175 ± 40	241 ± 46	<.001
Intraoperative inotropes, n (%)	1075 (21.7)	813 (11.4)	<.001
Intraoperative IABP, n (%)	109 (2.2)	185 (2.6)	.187
Graft distribution			
LAD territory, n (%)	4923 (99.4)	7104 (99.6)	.158
Circumflex territory, n (%)	3705 (74.8)	6006 (84.2)	<.001
RCA territory, n (%)	4190 (84.6)	5949 (83.4)	.083
Conduit used			
LIMA, n (%)	4884 (98.6)	7005 (98.2)	.101
RIMA, n (%)	277 (5.6)	414 (5.8)	.651
Radial artery, n (%)	4022 (81.2)	5763 (80.8)	.589
SVG, n (%)	4108 (82.9)	5849 (82.0)	.190
Conversion to CPB, n (%)	138 (2.8)		

*Data are presented as the mean ± SD where appropriate. OPCAB indicates off-pump coronary artery bypass; CCAB, conventional coronary artery bypass; CPB, cardiopulmonary bypass; ACC, aortic cross-clamp; IABP, intra-aortic balloon pump; LAD, left anterior descending artery; RCA, right coronary artery; LIMA, left internal mammary artery; RIMA, right internal mammary artery; SVG, saphenous vein graft.

Table 4. Postoperative Results and 30-Day Mortality*

Variables	OPCAB Group (n = 4953)	CCAB Group (n = 7133)	*P*
Intubation time, h	19 ± 4	25 ± 6	<.001
Postoperative inotropes, n (%)	322 (6.5)	428 (6.0)	.278
Blood loss, mL	350 ± 41	598 ± 74	<.001
Blood and blood product transfusion, n (%)	1525 (30.8)	3231 (45.3)	<.001
Postoperative IABP, n (%)	64 (1.3)	185 (2.6)	<.001
Perioperative MI, n (%)	79 (1.6)	136 (1.9)	.228
Reoperation for bleeding, n (%)	30 (0.6)	199 (2.8)	<.001
Atrial fibrillation, n (%)	538 (10.9)	1348 (18.9)	<.001
Stroke, n (%)	40 (0.8)	86 (1.2)	.043
Prolonged ventilation, n (%)	185 (3.7)	477 (6.7)	<.001
Renal dysfunction, n (%)	70 (1.4)	114 (1.6)	.459
ICU stay, h	23 ± 6	34 ± 8	<.001
Pulmonary infection, n (%)	144 (2.9)	257 (3.6)	.041
Sternal infection, n (%)	54 (1.1)	100 (1.4)	.156
Operative mortality, n (%)	48 (0.97)	133 (1.86)	<.001
Hospital stay, d	5 ± 2	8 ± 3	<.001

*Data are presented as the mean ± SD where appropriate. OPCAB indicates off-pump coronary artery bypass; CCAB, conventional coronary artery bypass; IABP, intra-aortic balloon pump; MI, myocardial infarction; ICU, intensive care unit.

Ascione 1999, Calafiore 2001, Arom 2000a]. We found that postoperative blood loss and blood requirements were reduced in the OPCAB group. This result has also been shown in other studies [Brasil 1998, Ascione 1999]. In a prospective study, Ascione and colleagues [Ascione 2001] showed that postoperative blood loss, transfusion requirements, and transfusion-related costs were lower than with conventional CABG on CPB and cardioplegic arrest. This finding is important, because transmission of viral infections, induction of immunologic transfusion reactions, and suppression of the immune system remain important risks related to the transfusion of blood and blood products despite improvements in donor-screening methods [Consten 1996].

Patients in the OPCAB group were extubated early, fewer patients required prolonged ventilation, and the incidence of lung infection was lower, although the incidence of patients with chronic obstructive pulmonary disease was higher and the patients were older in this group. OPCAB has been shown to be associated with decreased morbidity and mortality in high-risk patients, including the elderly, patients with poor left ventricular function, renal dysfunction, left main stenosis, or chronic obstructive pulmonary disease, and patients with prior neurologic dysfunction [Arom 2000b, Boyd 1999].

Most of the studies that have compared the outcomes of OPCAB and CCAB procedures are retrospective and come from a single center. Hernandez and colleagues described their multicenter experience of in-hospital outcomes for off-pump versus on-pump CABG [Hernandez 2001]. Patients in the off-pump group had a significantly reduced need for intraoperative or postoperative intra-aortic balloon pump, a decreased incidence of postoperative atrial fibrillation, and a shorter hospital stay.

Randomized controlled trials also have demonstrated that OPCAB is associated with less renal dysfunction, a lower level of troponin release, fewer arrhythmias, a mitigation of perioperative inflammatory response, a lower risk of infection, and significant reductions in the duration of hospital stay and costs than with CABG on CPB [Ascione 1999].

Many surgeons prefer to use OPCAB for patients with the surgically most favorable coronary arteries. Initially, we were also using OPCAB for patients with a suitable anatomy. Currently, all patients admitted for isolated CABG procedures in our institute are considered for OPCAB, irrespective of the severity of coronary artery disease, and they include those with left main disease, poor left ventricular function, and distal coronary artery disease requiring endarterectomy. In our experience and that of some other investigators [Naseri 1999], it is safe and feasible to perform coronary endarterectomy on the beating heart. The number of patients with multivessel coronary artery disease undergoing OPCAB at our

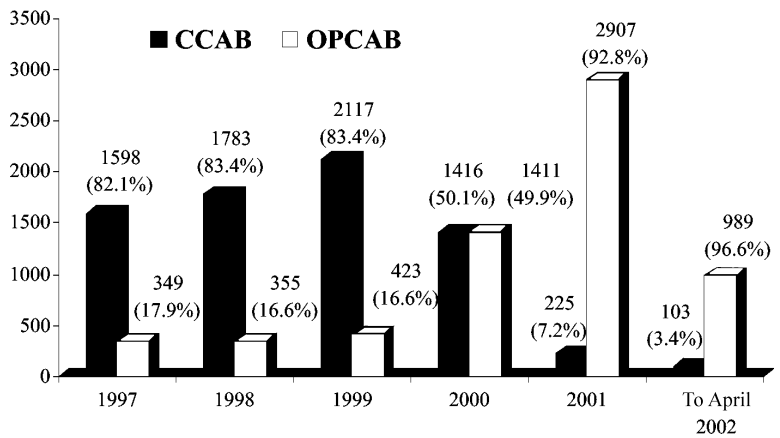

Figure 2. Number of patients undergoing off-pump coronary artery bypass (OPCAB) and conventional coronary artery bypass (CCAB) between July 1997 and April 2002.

institute has increased from 17.9% in 1997 to 96.6% in 2002 (Figure 2). The policy change from performing CABG on CPB to routinely attempting OPCAB has been shown to be safe and effective despite the increased learning curve for OPCAB [Anyanwu 2002].

We have used intracoronary shunts in most patients during distal coronary anastomosis procedures. Positioning and stabilization of the heart in OPCAB, especially during circumflex and posterior descending artery anastomosis, are associated with significant hemodynamic changes [Mathison 2000]. These changes may be further exacerbated by the snaring of the coronary arteries. Several clinical studies have shown the effectiveness of intracoronary shunts for maintaining myocardial perfusion to avoid ischemia of target vessels during OPCAB [Lucchetti 1999], although the use of shunts is not widespread and remains controversial. We have found intracoronary shunts especially useful in situations in which the coronary artery does not have a critical stenosis, especially in a dominant, large right coronary artery.

Complete revascularization is believed to be important in producing a reintervention-free result following OPCAB. In a 7-year follow-up study by Gundry and colleagues [Gundry 1998] that compared off-pump and on-pump CABG, the reintervention rate in the off-pump group was up to 3 times higher than that of the on-pump group, although the survival rates remained similar. This difference was attributed to incomplete revascularization in the off-pump group, in which the average number of grafts was 2.4, compared with the on-pump group, in which the average number of grafts was 3.2. This trend toward fewer grafts among OPCAB patients has been reported by many studies [Arom 2000a, Puskas 2001]. It has been suggested that the difference in the number of grafts between the off-pump and on-pump groups may be narrowing as surgeons gain more experience [Hart 2000]. In our study, the average number of grafts was also lower in the OPCAB group than in the CCAB group. This difference has decreased each year, and in the last 2 years we have found no significant difference between the two groups of patients in the average number of grafts. In our experience, complete myocardial revascularization can be achieved on the beating heart.

Neurologic deficit after CABG still represents a devastating complication. The mechanisms contributing to neurologic injury are multifactorial. Some surgeons have found decreased rates of stroke following OPCAB in high-risk patients [Ricci 2002]. We also found that the incidence of stroke was lower in the OPCAB group than in the CCAB group. In a study of 226 consecutive unselected patients, Patel and colleagues found a significantly decreased incidence of focal neurologic deficit in the off-pump group than in the on-pump group [Patel 2002].

Hospital mortalities for off-pump and on-pump CABG have been shown to be comparable in most studies [Hernandez 2001, Arom 2000b, Puskas 1998]. In our study, mortality in the OPCAB group was lower than in the CCAB group. Other studies have also demonstrated lower mortality in off-pump CABG compared with on-pump CABG [Plomondon 2001, Calafiore 2001, Arom 2000a].

The limitations of our study are that it is a retrospective study and the patient population is not homogeneous. In addition, there may be some selection bias on the part of the surgeon. Plomondon and colleagues [Plomondon 2001] have reported a lower risk-adjusted morbidity and mortality with off-pump surgery.

In conclusion, OPCAB is a safe and effective procedure and can be used to achieve complete myocardial revascularization in patients with multivessel coronary artery disease. With experience, the surgeon can consider almost all patients for OPCAB. OPCAB is associated with a reduced morbidity and mortality compared with patients who undergo on-pump procedures. However, large prospective randomized trials that include postoperative angiography are required to find out the real benefits of OPCAB compared with CABG on CPB.

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REVIEW AND COMMENTARY

1. Editorial Board Member DB515 writes:

This is a good paper reporting on a comparison between OPCAB and on-pump coronary artery bypass (ONCAB) in a retrospective manner. I think it is important in this setting to explain rather specifically how the data were collected and what kind of quality control of the data was in effect during the study. In addition, the OPCAB technique should be described in some further detail. The following issues must be addressed:

a) At what point was the decision for OPCAB/ONCAB made? Was it decided at scheduling after opening the chest or at another point? This is important to evaluate the conversion rate.
b) Did the same surgeons do all operations, or were there two different groups of surgeons?
c) Were the minimally invasive direct coronary artery bypasses (MIDCABs) included? It is stated that the OPCAB program was started with MIDCAB but that later on all OPCAB was through a median sternotomy.
d) Were graft verification techniques used such as transit time flow measurements?

Authors' Response by Zile Singh Meharwal, MD:

a) The decision to operate on a patient on-pump or off-pump was made by the operating surgeon before surgery. Initially, off-pump surgery was performed in selected patients, and the decision was mainly made from the coronary anatomy and associated comorbidities that contraindicated the use of CPB. The data were collected and entered into our database preoperatively. The analysis was done retrospectively. Currently, all patients are considered for OPCAB.
b) We have 6 surgeons in our group who performed these operations. The study represents the collective experience of these surgeons.
c) In the present study, we have not included MIDCAB procedures. The study describes our experience with OPCAB in patients who required 2 or more grafts and were operated on through a median sternotomy.
d) We do not routinely measure the flow in the grafts. The graft flows were, however, measured whenever there were any signs of ischemia, either by electrocardiography or transesophageal echocardiography or when there was any question regarding the quality of the anastomosis.