Coronary Artery Bypass: the Increasing Role of Off-Pump Surgery in a Large Community Hospital

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ABSTRACT

Background: This study compares the results of myocardial revascularization with sternotomy without cardiopulmonary bypass (OPCAB) with conventional coronary artery bypass grafting (CCAB) at a single institution during a recent time period.

Methods: The charts of 1,172 patients undergoing coronary bypass grafting via a median sternotomy at the Lehigh Valley Hospital between January 1, 1999 and June 30, 2000 were retrospectively reviewed. Patients who underwent revascularization through a thoracotomy with or without cardiopulmonary bypass and those who had concomitant carotid endarterectomy were excluded. Continuous outcomes were compared using the Student's *t*- test; binary outcomes were compared using a chi-squared test. Logistic regression was used to estimate risk of mortality due to conversion to standard incision.

Results: OPCABs accounted for 11.08% (45/406), 17.18% (67/390), and 35.37% (133/376) of the procedures in the first, second, and third 6-month periods, respectively. OPCAB and CCAB patients were similar in regard to age, gender, race, ejection fraction, left mainstem stenosis, and major comorbidities. CCAB patients had a higher incidence of previous coronary bypass grafting (7.66% vs. 2.45%) but a lower incidence of other prior cardiac surgical procedures (0.43% vs. 2.04%) compared to OPCAB patients. Postoperatively OPCAB patients had a lower incidence of stroke (0.41% vs. 2.80%), sternal wound infection (0.00% vs. 0.43%), red blood cell transfusion (50.40% vs. 64.50%), and readmissions within 30 days (0.82% vs. 3.34%). There were no significant differences in total hospital costs, length of stay, or the incidence of perioperative myocardial infarction, postoperative atrial fibrillation, or renal insufficiency in the two groups. There was a trend toward decreased mortality, fewer pulmonary complications, and shorter duration of ventilator support in the OPCAB patients, but none of these differences were statistically significant. OPCAB patients had a higher incidence of reoperation for graft dysfunction (2.86% vs. 0.43%), and 8.16% (20/245) required conversion to CCAB. The adverse effects of conversion to CCAB included increased cost ($35,547 vs. $17,987, $p = 0.0441$), length of stay (13.3 days vs. 7.9 days, $p = 0.0195$), and mortality (5.00% vs. 0.44%, $p = 0.0300$).

Conclusion: The early results of myocardial revascularization without cardiopulmonary bypass are equal to or better than conventional bypass procedure outcomes in most patients.

INTRODUCTION

Surgical revascularization for ischemic heart disease has become widely accepted. Indications have broadened and the surgical population has become older with increased operative risks [Avery 2000]. In the past few years, there have been dramatic changes in surgical myocardial revascularization—changes that are driven by the desire to improve outcomes while reducing costs, competition for a shrinking volume of patients, and public demand. Coronary artery bypass without cardiopulmonary bypass has become an increasingly common technique to achieve these ends [Bergsland 1998, Shennib 1999, Hart 2000, Hart 2001].

MATERIALS AND METHODS

Setting

Lehigh Valley Hospital is a large (617-bed) university-affiliated community hospital in eastern Pennsylvania where between 1,100 and 1,200 cardiac surgical procedures are performed annually. All cardiac procedures are performed by attending surgeons in private practice.

Patients

Data were collected on the 1,172 patients in whom myocardial revascularization via the median sternotomy was performed as the sole cardiac procedure between January 1, 1999 and June 30, 2000. Information was abstracted from forms submitted to the Society of Thoracic Surgeons Database, as well as records of the Department of Perfusion, the hospital blood bank, and patient charts. Patients were excluded if they underwent concomitant carotid endarterectomy (N = 51) or if the coronary bypass operation was performed through a thoracotomy

without cardiopulmonary bypass (minimally invasive direct coronary artery bypass [MIDCAB], lateral MIDCAB [N = 12]) or port-access techniques (N = 12).

Surgical Technique

All patients underwent standard sternotomy. CCAB patients received 3 mg/kg of heparin and standard cardiopulmonary bypass, including moderate systemic hypothermia, aortic crossclamping, and cold blood and/or crystalloid cardioplegia administered antegrade and/or retrograde. Distal anastomoses were generally done first and proximal anastomoses were done with the crossclamp in place or with the application of a partial occlusion clamp. OPCAB patients received 1-2 mg/kg of heparin and were kept normothermic insofar as was possible. Efforts were made to maintain a mean blood pressure of 80 torr with a combination of Trendelenberg position, table tilting, and alpha agents. When the left internal mammary artery was used it was usually grafted to the left anterior descending artery prior to the performance of other anastomoses. In some instances, proximal distal anastomoses were performed first, and in others, distal anastomoses were performed first. Attempts were made to graft collateralized arteries prior to collateralizing ones. The heart was exposed by a combination of table tilting, deep pericardial sutures, slings, and laparotomy pads placed beneath the heart. Stabilization of target arteries was accomplished with commercially available stabilizers, mostly Octopus II. The grafted arteries were occluded proximally and occasionally distally with either coronary bulldog clamps or silastic loops. Intracoronary shunts were rarely used. Misted blowers provided improved visualization. No pharmacologic methods were used to slow the heart and pre-ischemic conditioning was not routinely used. Conversion from OPCAB to CCAB was considered to have occurred if any coronary arteriotomy had been performed prior to institution of cardiopulmonary bypass or if

hemodynamic deterioration during manipulation of the heart resulted in the need for emergency institution of cardiopulmonary bypass.

Statistical Analysis

Comparisons of both patient characteristics and outcomes were made between CCAB and OPCAB patients. Continuous characteristics and outcomes were compared using Student's *t*-test and binary outcomes were compared using a chi-squared test. Risk of mortality associated with conversion to standard incision was estimated using logistic regression. All analyses were performed with SAS statistical software (version 8.1, Cary, North Carolina). In all analyses, statistical significance was defined as $p < 0.05$.

RESULTS

Table 1 compares the clinical characteristics of the CCAB and OPCAB patients. They were similar in regard to age, gender, race, ejection fraction, incidence of left mainstem stenosis, and major comorbidities (hypertension, diabetes, renal insufficiency, cerebrovascular disease, history of stroke, and smoking history). More CCAB than OPCAB patients had prior coronary bypass surgery (7.66% vs. 2.45%, $p = 0.0034$), but OPCAB patients had a higher incidence of other prior cardiac surgical procedures (2.04% vs. O.43%, $p = 0.0103$). Patients in the CCAB group had more diseased arteries than those in the OPCAB group (2.767 vs. 2.561, $p = 0.0001$). OPCABs accounted for an increasing percentage of revascularization procedures in each of the succeeding 6-month time periods of the study---11.08%, 17.18%, and 35.37%, respectively (Figure 1). All but one of the eight surgeons performed OPCABs, but the frequency of off-pump procedures varied widely among the surgeons (Figure 2).

Table 2 compares the priority status of the two groups. Urgent and emergent/salvage operations were more common in the CCAB patients; there was a higher percentage of elective patients in the OPCAB group. There were differences in the number of grafts, the arteries grafted, and the conduits in the two groups (Table 3). CCAB patients received an average of 3.80 grafts compared to 3.09 grafts in the OPCAB group ($p = 0.0001$). Although the left anterior descending coronary artery was grafted in nearly all patients, the right coronary artery and its major branches and the circumflex system were grafted less often in the off-pump patients. Radial arteries were not commonly used in this series, but this conduit was used more often in the OPCAB group.

Stroke, sternal wound infection, red blood cell usage, and readmissions within 30 days were significantly lower in the OPCAB group (Table 4). There was no difference in the incidence of perioperative myocardial infarction, postoperative atrial fibrillation, re-exploration for bleeding, or deterioration in renal function in the two groups. There was a trend toward decreased mortality, neurological complications (excluding stroke), and pulmonary complications in the OPCAB patients, but none of these differences reached statistical significance. OPCAB patients had a significantly higher incidence of re-operation for graft dysfunction than CCAB patients (2.86% vs. 0.43%, $p = 0.0005$).

Conversion from OPCAB to CCAB was required in 8.16% (20/245) of cases. Conversion occurred in 15.55% (7/45), 5.97% (4/67), and 6.77% (9/133) of the patients in the first, second, and third 6-month intervals of the study period. Four of the seven surgeons who performed OPCAB procedures, including those with the largest number of cases, had conversions. Table 5 lists the indication for institution of cardiopulmonary bypass in this group of 20 patients. Of the 11 patients in whom

hypotension/exposure was the primary indication, 8 patients had a target artery that was either a branch of the circumflex or a ramus intermedius. In one patient, it was a diagonal artery, and in another patient, hypotension occurred after placing a partial occlusion clamp on the ascending aorta. One patient repeatedly developed ischemic EKG changes when the circumflex branch was temporarily occluded, and the surgeon did not feel that it was safe to proceed without cardiopulmonary bypass. One patient suddenly developed ventricular fibrillation during the performance of a circumflex anastomosis. That patient was successfully defibrillated, and the anastomosis was completed on-pump. Four patients had problems with a target artery. In two patients the LAD was so diffusely diseased that the surgeons did not feel comfortable performing the anastomoses on the beating heart. In one patient an intramuscular LAD was the reason for conversion, and in one a calcified right coronary artery required an endarterectomy. Of these 20 patients, the only death occurred in a patient who suffered an aortic dissection at the site of a partial occlusion clamp. The injury was recognized intraoperatively, but the repair was unsuccessful.

The need to convert to CCAB resulted in increased costs, length of stay, and mortality (Table 6). OPCAB patients not requiring conversion had a cost reduction of $1,949 compared to CCAB patients; whereas in those in whom conversion was needed, the cost nearly doubled and the length of stay increased by 5.4 days. Logistic regression analysis suggested OPCAB patients not converted were 80% less likely to die than CCAB patients ($p = 0.129$), but those who required conversion were 12.5 times more likely to die ($p = 0.078$). Neither effect reached statistical significance.

DISCUSSION

This report is reflection of a stage in the evolution of off-pump coronary bypass grafting at a large community hospital. Several studies have indicated that the results in OPCAB are equal to or better than those in CCAB [Mack 1998, Cremer 2000, Puskas 2001], which begs the question of why most coronary bypass operations are performed in the traditional manner.

The techniques of bypass grafting on the beating heart are taxing for the surgeon, especially in the early stages of his or her experience. Even with a full sternotomy and the potential for rapid institution of cardiopulmonary bypass, the realities of operating on a moving target, blood in the field, time constraints, and hemodynamic compromise make the experience very uncomfortable for the operator. It appears that these fears may be justified considering the poor results in those patients in whom the attempt at off-pump surgery were not successful---those who required conversion to CCAB or return to the operating room for graft revision. We suspect that the suboptimal results in the present study are part of the "learning curve." One should be able to predict with a high degree of reliability which target arteries are unsuitable for off-pump grafting. Likewise, the problems encountered with exposure of ramus intermedius and circumflex branches are likely a reflection of the inexperience of the surgeons in this report. Aortic injury from a partial occlusion clamp has been reported to be increased in off-pump surgery [Chavanon 2001]. Conversion from OPCAB to CCAB should be infrequent [Amrani 2000, Perkowski 2001]. Other factors that limit the growth of off-pump bypass surgery are skepticism regarding both short- and long-term patency of graft performed without cardiopulmonary bypass and concern that small or difficult to reach target arteries will be not be grafted or poorly grafted. In the present series,

the right coronary and circumflex systems were grafted less frequently in the OPCAB patients. It is possible that some of the OPCAB patients might not have received complete revascularization. The fact that OPCAB patients had fewer diseased arteries mitigates this concern. It is also likely that the surgeons specifically selected patients with a lower incidence of right coronary and circumflex disease for OPCABs.

CONCLUSION

There are definite problems associated with off-pump surgery; however, even in the developmental stages of a program, the results appear equal to or better than those of conventional myocardial revascularization.

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Table 1. Preoperative Characteristics of CCAB and OPCAB Groups

	CCAB (N=927)	OPCAB (N=245)	p value
Age	65.171	66.518	0.1857
Female	24.54%	28.57%	0.5234
Non-white	0.97%	0.41%	0.3044
Ejection fraction	49.154	49.226	0.9413
Left mainstem stenosis	29.45%	28.28%	0.7204
Hypertension	66.23%	62.45%	0.2681
Diabetes mellitus	29.98%	33.06%	0.3520
History of smoking	55.30%	60.82%	0.1218
Current smoker	18.49%	22.16%	0.2420
Renal insufficiency	5.84%	6.12%	0.8695
History of stroke	5.09%	6.12%	0.5201
Cerebrovascular disease	8.77%	11.43%	0.2026
Number of diseased vessels	2.767	2.561	0.0001
Prior coronary bypass	7.66%	2.45%	0.0034
Prior other cardiac surgery	0.43%	2.04%	0.0103

Table 2. Priority Status of CCAB and OPCAB Groups, p = 0.027

	CCAB		OPCAB	
Status	N	Percent	N	Percent
Elective	220	23.73%	75	30.61%
Urgent	632	68.18%	161	65.71%
Emergent/salvage	75	8.09%	9	3.67%

Table 3. Number of Grafts (Distal Anastomoses), Arteries Grafted, and Conduits in CCAB and OPCAB Patients

	CCAB (N=927)	OPCAB (N=245)	p value
Number of Grafts (Distal Anastomoses)	3.800	3.094	0.0001
Arteries grafted			
LAD*	98.60%	99.18%	0.3986
RCA**	44.77%	37.55%	0.0426
CIRC***	80.58%	67.37%	0.0001
Conduits used			
Vein	100%	100%	1.000
IMA	91.5%	91.4%	0.9861
Radial artery	0.98%	2.86%	0.0019

* Left anterior descending coronary artery and/or diagonal branches.
** Right coronary artery and/or any of its branches.
*** Circumflex coronary artery and/or any of its branches.

Table 4. Outcomes in CCAB and OPCAB Groups

	CCAB (N=927)	OPCAB (N=245)	p value
Total hospital costs ($)	19,036	19,421	0.5886
Total length of stay (days)	8.553	8.286	0.4677
Readmission within 30 days	3.34%	0.82%	0.0334
Prolonged ventilator support	5.75%	2.86%	0.1964
Mortality	1.73%	0.82%	0.3031
Myocardial infarction	0.43%	0.82%	0.4529
All neurological complications	4.14%	2.54%	0.2521
Stroke	2.80%	0.41%	0.0300
Sternal wound infection	0.43%	0.00%	0.02616
Atrial fibrillation	8.85%	11.43%	0.2176
Renal insufficiency	2.29%	3.42%	0.3254
RBC transfusion			
Incidence	64.50%	50.40%	0.0001
Mean number of units	2.71	1.86	0.0002
Pulmonary complications	5.23%	3.40%	0.2444
Re-exploration for bleeding	1.73%	1.63%	0.9201
Re-exploration for graft dysfunction	0.43%	2.86%	0.0005

Table 5. Reason for Conversion from OPCAB to CCAB

	Hypotension/Exposure	Hypotension/ Ischemic EKG	Target Artery	Rhythm	Bleeding
No.	11	3	4	1	1

Table 6. Adverse Effects of Conversion in OPCAB

OPCAB (N=245)

	Conversion to CCAB (N=20)	No Conversion To CCAB (N=225)	p value
Cost	$35,547	$17,987	0.0441
Length of stay	13.3	7.9	0.0195
Mortality	5.00%	0.44%	0.0300

Figure 1. CCAB and OPCAB Procedures for Three 6-month Intervals

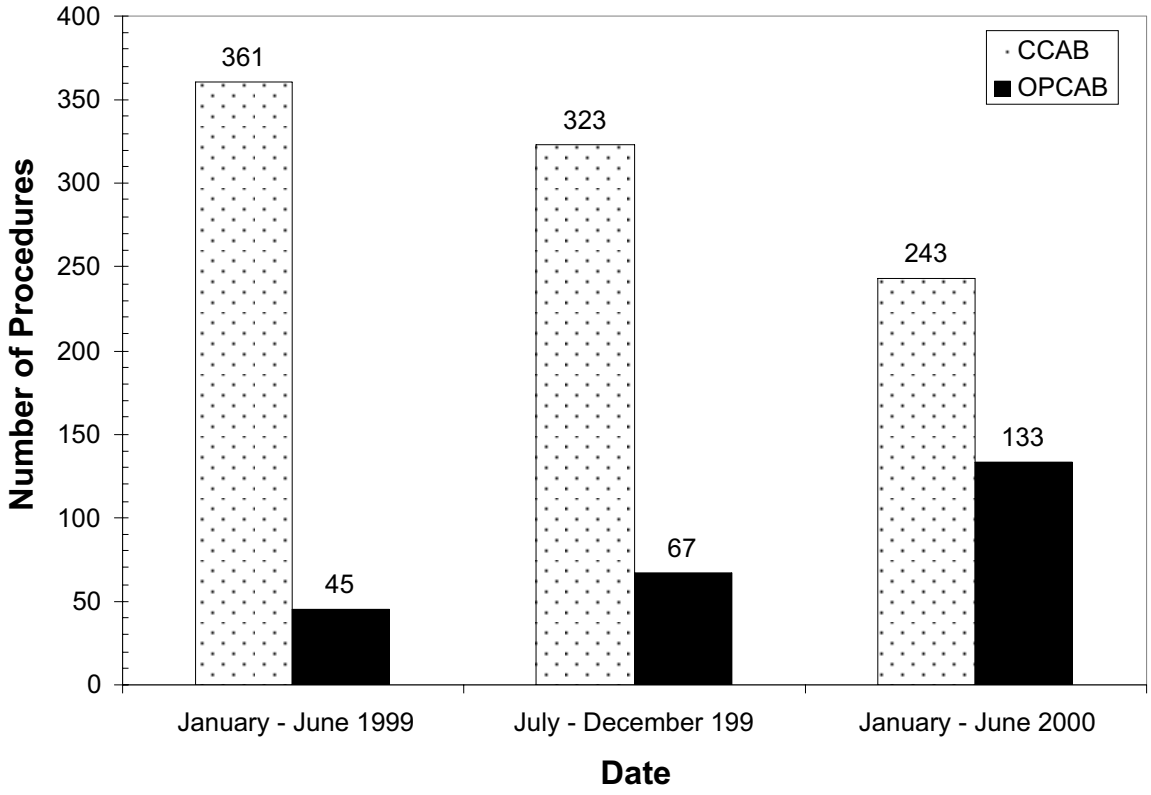

Figure 2. CCAB and OPCAB Procedures by Surgeon