The Heart Surgery Forum #2004-1148
8 (1), 2005 [Epub December 2004]
doi:10.1532/HSF98.20041148

Online address: www.hsforum.com/vol8/issue1/2004-1148.html

Outcomes for Off-Pump Coronary Artery Bypass Grafting in High-Risk Groups: A Historical Perspective

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ABSTRACT

Background: The outcomes of off-pump coronary artery bypass (OPCAB) and conventional coronary artery bypass grafting with cardiopulmonary bypass (cCABG) have been compared in detail. Similarly, several reports have examined outcomes of high-risk subsets of patients in OPCAB as a selection strategy for reducing morbidity and mortality compared to cCABG. We undertook a retrospective study comparing outcomes from the early years in our experience of beating-heart surgery in high-risk patients selected for OPCAB compared to low-risk patients having OPCAB. This study was premised on strict selection criteria in an era prior to stabilizing devices and cardiac positioners.

Methods: A total of 384 patients underwent OPCAB over a 10-year period. Clinical outcomes were compared for 280 low-risk patients and 104 high-risk patients (redo CABG, CABG with simultaneous carotid endarterectomy, or renal insufficiency/failure).

Results: The high-risk group patients were significantly older than the low-risk group patients (64.3 ± 10.5 years versus 61.5 ± 11.7 years, respectively, $P = .048$). The high-risk group also had a greater degree of left ventricular dysfunction ($P < .001$), a higher incidence of diabetes ($P = .046$), and a higher proportion of patients with peripheral vascular disease ($P = .009$). There was no significant difference in the number of grafts created, but there was a statistical difference in the type of graft used. The high-risk group received fewer internal thoracic artery grafts ($P = .005$) and more saphenous vein grafts ($P = .041$). The high-risk group had slightly prolonged median lengths of stay in the intensive care unit (2.2 versus 1.4 days, $P < .001$) and hospital (11 versus 8 days, $P < .001$) and a higher proportion of patients requiring blood transfusions (48% versus 24%, $P < .001$), yet there was no significant difference in major adverse outcomes.

Conclusions: In this retrospective and historical review, OPCAB was found to be equally safe in carefully selected high- and low-risk patients. These results provided for the enthusiasm and innovation to expand the usage of OPCAB in patients with coronary artery disease.

INTRODUCTION

Coronary artery bypass grafting (CABG) represents the majority of cardiac procedures performed today. The procedure itself has remained essentially unchanged for decades save for some alterations in cardioprotectants [Weintraub 2003]. Over the course of its development, CABG has come to be a reliable, safe, and effective procedure with well-defined outcomes and morbidities; the cause of the latter, for the most part, can be attributed to the adverse affects of cardiopulmonary bypass (CPB).

In an attempt to improve on CABG, off-pump coronary artery bypass (OPCAB) or beating-heart surgery was developed [Pfister 1992]. Early data suggested that OPCAB was associated with lower rates of atrial fibrillation, cerebrovascular accidents (CVAs), transfusion requirements, use of inotropes, and renal damage. In addition, intensive care unit (ICU) and hospital stays were shortened, with a decrease in costs [Pfister 1992, Ascione 2001, Puskas 2003].

Impaired renal function, reoperative or redo CABG, carotid artery disease, and left ventricular dysfunction are independent predictors of increased operative morbidity and mortality after CABG [Del Rizzo 1996, Trachiotis 1997, 1998, 1999]. These high-risk individuals have been shown to have higher perioperative mortality rates and to consume more health care resources than their low-risk counterparts [Edwards 1994, Del Rizzo 1996]. Moreover, the favorable outcomes with current OPCAB techniques compared to cCABG in these high-risk subgroups have led to a preferential patient selection strategy for OPCAB. [Trachiotis 1997, 1999, 2004, Dewey 2004]. We evaluated preoperative characteristics and postoperative outcomes, comparing low- and high-risk patients who were selected for OPCAB premised on specific patient and technical selection criteria in the early era prior to vessel stabilization devices and cardiac positioners.

MATERIALS AND METHODS

All OPCABs performed at the Washington Hospital Center between 1985 and 1995 were retrospectively reviewed. A total of 384 patients underwent OPCAB during the study

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Received October 4, 2004; accepted October 5, 2004.

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Table 1. Baseline and Intraoperative Characteristics of the Patients*

Characteristic	Low-Risk Group (N = 280)	High-Risk Group (N = 104)	*P*
Age, y	61.5 ± 11.7	64.3 ± 10.5	.048
Male sex, n (%)	203 (72)	68 (65)	.217
Left ventricular function, n (%)			
Normal	203 (72)	55 (53)	<.001
Mildly decreased	47 (17)	26 (25)	.094
Moderately decreased	27 (10)	19 (18)	.033
Severely decreased	3 (1)	4(4)	.169
Diabetes, n (%)	48 (17)	28 (27)	0.046
Peripheral vascular disease, n (%)	9 (3)	11 (11)	0.009
Chronic obstructive pulmonary disease, n (%)	12 (4)	2 (2)	0.429
Congestive heart failure, n (%)	3 (1)	1(1)	0.637
Hypertension, n (%)	138 (50)	62 (60)	0.092
Mean No. of grafts	1.29 ±0.5	1.19 ±0.4	0.183
Type of graft, n (%)			
Saphenous vein	61 (22)	38 (37)	.005
Internal thoracic artery	192 (68)	60 (58)	.041
Saphenous vein and internal thoracic artery	27 (10)	5 (5)	.188
Internal thoracic artery with saphenous vein extension	0 (0)	1 (1)	.606

*Plus-minus values are means ± SD.

period. These patients constitute 2.5% of all patients undergoing CABG during the study period and represents our early experience with OPCAB.

Patients whose operation was performed off-bypass (OPCAB) were selected according to certain criteria. Only those patients requiring grafts in the right coronary artery or left anterior descending coronary artery systems were eligible. Patients requiring a circumflex graft underwent surgery performed on bypass. Among eligible patients, OPCAB was offered preferentially to (1) patients who needed only grafts to the left anterior descending and right coronary systems, (2) patients with heavily calcified aortas, (3) patients who had had previous cardiac operations, (4) patients with cerebrovascular accidents, (5) patients on dialysis or with very impaired renal function, and (6) Jehovah's Witness patients [Pfister 1992]. All patients were assessed for complete revascularization. The procedure was performed through a median sternotomy, and vessel stabilization was performed with a coated vascular clamp or a bent fork. For the purposes of this study, we compared patients who met operative eligibility requirements undergoing a first-time OPCAB (considered low-risk) to those who were considered high-risk. High-risk patients conformed to Society of Thoracic Surgeons (STS) known risks factors and were defined as those undergoing redo CABG, those with renal insufficiency or failure (creatinine > 2.0 mg/dL or requiring dialysis), and those undergoing simultaneous CABG and carotid endarterectomy (CEA).

The statistical analysis was performed using SigmaStat statistical software (Jandel Scientific, San Rafael, CA, USA). The statistical tests applied were the Student *t* test and the Mann-Whitney Rank Sum Test when the equal variance test was violated. The chi-square test was used for categorical values. $P < .05$ was considered statistically significant.

RESULTS

From 1985 to 1995, 384 OPCABs were performed: 280 low risk and 104 high risk. Of the high-risk group patients, 80 underwent redo CABG, 17 had renal insufficiency (n = 9) or dialysis-dependent renal failure (n = 8), and 7 underwent simultaneous CABG/CEA [Trachiotis 1997]. Table 1 shows the baseline and intraoperative characteristics of the patients. The high-risk group was slightly older, with a mean age of 64.3 years compared to 61.5 years in the low-risk group ($P = .048$). There was no significant difference in sex distribution between the 2 groups, with an average of 68.5% of the patients being men.

There was a similar distribution of chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), and hypertension (HTN) in the 2 groups. However, there was a significant difference in left ventricular (LV) function, diabetes, and peripheral vascular disease (PVD). LV function was worse in the high-risk group, with only 53% having normal LV function compared to 72% in the low-risk group ($P < .001$). There was a higher incidence of moderately decreased LV function in the high-risk group (18% versus 10%, $P = .033$), whereas there was no significant difference between the 2 groups in the incidence of mildly and severely depressed LV function. Diabetes was more pronounced in the high-risk group than in the low-risk group (27% versus 17%, $P = .046$), as was PVD (11% versus 3%, $P = .009$).

Intraoperative data revealed the mean number of grafts to be similar in the 2 groups (1.29 in the low-risk and 1.19 in the high-risk group). The low-risk group more frequently underwent bypass with internal thoracic arteries (ITA) (68% versus 58%, $P = .041$), whereas the high-risk group received a higher proportion of saphenous vein grafts (SVG) (37% versus 22%, $P = .005$).

Postoperative data and adverse events are given in Table 2. There was no significant difference between the 2 groups in death rates during the first 30 days after surgery (5 deaths in the low-risk group and 1 death in the high-risk group) or in the 1 to 3 months after surgery (1 death in the low-risk group and no deaths in the high-risk group). Similarly, the rates of

Table 2. Postoperative Data and Adverse Events

Variable	Low-Risk Group (N = 280)	High-Risk Group (N = 104)	*P*
Death within 30 days, n	5	1	.908
Death in 1 to 3 months, n	1	0	.606
Median stay in intensive care unit, d	6	7	<.001
Median postoperative hospital stay, d	8	11	<.001
Postoperative stroke, n	0	1	.606
Postoperative myocardial infarction, n	1	2	.370
Need for inotropes/pressors, n (%)	86 (31)	36 (35)	.544
Need for transfusion, n (%)	68 (24)	50 (48)	<.001

postoperative CVA and myocardial infarctions (MI) were not significantly different. In particular, there were no cerebral embolic events in the OPCAB/CEA group, and no new cases requiring dialysis in the renal failure group. Although slight, there was a significant difference in median ICU and hospital stays, with the high risk patients staying slightly longer (7 versus 6 days in the ICU, $P < .001$, and 11 versus 8 days in the hospital, $P < .001$). The use of inotropic support and pressers was similar in both groups. However, transfusion rates were significantly higher in the high-risk group (48% versus 24% requiring transfusion, $P < .001$).

DISCUSSION

In this study we found that high-risk and low-risk OPCAB patients had similar postoperative morbidity (2% versus less than 1%) and mortality rates (1% versus 2%) in spite of the high-risk group having statistically greater ages and higher rates of diabetes, peripheral vascular disease, and left ventricular dysfunction. Our mortality rates concur with previously published results for on- or off-bypass CABG [Trehan 2000, Connolly 2003, Puskas 2004, Weintraub 2003, Trachiotis 2004].

Although in our group the mean number of grafts was similar, with 1.29 in the low-risk group and 1.19 in the high-risk group, the types of grafts were significantly different. In the high-risk group, there was a statistically lower incidence of ITAs (58% versus 68%, $P = .041$), reflecting the high proportion of high-risk patients that were redo CABGs (77%). As a result, our high-risk patients received a greater proportion of SVGs compared to the low-risk patients (37% versus 22%, $P = .005$). This factor has long-term outcome implications, because ITAs have demonstrably longer patency rates than SVGs [Geha 1975, Tyras 1980, Sethi 1991]. However, long-term follow-up (mean 10 years) of 151 of these patients shows greater than 90% survival and no difference between internal mammary artery (IMA) and SVG graft to the LAD [Trachiotis 1999]. This excellent survival result highlights the bias to selecting patients with mainly LAD disease and the durability of any conduit to this coronary territory.

OPCAB patients with a history of diabetes or low ejection fraction have been studied in the past. It was found that low ejection fractions are not a contraindication to OPCAB [Abraham 2000, Dewey 2004, Trachiotis 2004] and that diabetics have a decreased incidence of CVAs with OPCAB compared to CABG with CPB [Abraham 2001]. Again, these reports appear to be supported by our data; our high-risk patients had a significantly higher proportion of cardiac dysfunction and diabetes, yet their outcomes were not adversely affected.

Our success with the specific subgroups of high-risk patients continues to provide support to the existing literature. OPCAB/CEA has been espoused as a safe procedure, and we had no mortalities or morbidities in this group [Meharwal 2002]. Our data also concurs with D'Ancona's finding that avoiding CPB in redo CABGs decreases adverse outcomes [D'Ancona 2000]. Additionally, in our review of simultaneous CABG/CEA as a treatment strategy for symptomatic disease, we suggested and reported on a subset of patients that had simultaneous OPCAB/CEA as an operative strategy to minimize aortic trauma and manipulation [Trachiotis 1997]. In this subset of patients (n = 8), there were no cerebral events or mortalities.

ICU and hospital stay times were significantly greater in the high-risk group. This result most likely represents the higher rate of significant comorbidities in the high-risk group and is not related to the operation itself. Although there was no significant difference in inotropic support required by the two groups, there was a significant difference in blood transfusion requirements, with 48% of high-risk patients versus 24% of low-risk patients requiring transfusion ($P < .001$). The high-risk group may have required more blood products secondary to the more extensive dissection necessary during redo CABGs and the oozing from scar tissue afterwards. Similarly, platelet dysfunction in the renal insufficiency patients may have contributed to blood loss. Numerous trials have shown that OPCAB patients require less time to extubation, fewer ICU days, and less inotropic support compared to CPB patients [Ascione 2003, Bucerius 2003, Connolly 2003, Reston 2003, Puskas 2004].

It is important to note that these data represent our early experience with OPCABs prior even to the use of cardiac stabilizers or positioners. Thus, for this review, patients were selected based on their suitability to undergo anterior vessel grafts or because they had risk factors for potential adverse events from CPB technique. Additionally, the operative technique, anesthesia, and postoperative care strategies were more traditional, and did not incorporate treatment strategies that we have learned and adopted over recent years. Thus, as vessel stabilizers and heart positioners were introduced in 1997 and 1998, we rapidly increased our OPCAB numbers to account for 50% to 70% of all CABG patients and began performing complete and multivessel revascularization on all patients, with a high percentage of IMA grafts. Our perioperative treatment strategies now focus on less traumatic drainage tubes, early extubation, cardiac ICU stays less than 24 hours, and reduced hospital stays. Although even current OPCAB is still performed through a sternotomy, this strategy has not prohibited early patient extubation, discharge from the hospital, or return to work. Long-term survival in our modern OPCAB treatment era compares favorably to conventional CABG, even in the higher risk group, with mean 5-year survival at 95% versus 88%, respectively ($P = .28$) [Trachiotis 2004].

One of the shortcomings of this study is that it represents early years in OPCAB techniques, and although we do have some survival data, the grafting strategy was highly targeted and angiographic results are not known. Although there has been recent concern with regard to OPCAB early graft patency, this data has mainly come from groups with small numbers and little prior OPCAB experience [Khan 2004]. There are other data, especially from centers or surgeons with prior OPCAB experience, that challenge these results and suggest angiographic patency that compares favorably to conventional CABG, regardless of conduit choice [Puskas 2004].

We can conclude from our data that high-risk OPCAB patients have midterm outcomes similar to low-risk OPCAB patients. In the early years our selection strategy for OPCAB, which predominantly included patients who were felt to be at risk for an adverse event from CPB or required anterior (LAD) vessel grafting, has proved to be a strategy that seems to apply even in today's criteria for selecting patients who will derive the best results from OPCAB [Trehan 2000, Yokoyama 2000, Akpinar 2001, Magee 2003, Dewey 2004, Trachiotis 2004]. Therefore, it is our firm belief that in today's current grafting era, OPCAB should be considered as the grafting technique of choice for patients at risk for adverse sequelae from CPB.

ACKNOWLEDGMENT

This manuscript is dedicated to the memory of and in tribute to Albert J. Pfister, MD. Dr. Pfister was a graduate of the George Washington University Thoracic Surgery Program and spent his subsequent years in practice in Washington, DC, educating and training those of us who followed. G.D.T.

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