Complete revascularization is compromised in off-pump coronary artery bypass grafting

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Objective: Patients who undergo off-pump coronary artery bypass grafting (OPCAB) commonly receive fewer bypass grafts and are more often incompletely revascularized compared with those receiving conventional coronary artery bypass (CCAB) recipients. Because this can compromise survival, we sought to determine whether patients undergoing OPCAB are incompletely revascularized and whether this affects long-term survival and freedom from cardiac events.

Methods: OPCAB cases (n = 411) performed from January 1, 1997 to June 30, 2003 were considered for inclusion and matching with 874 randomly selected, contemporary CCAB cases. After propensity matching, 308 OPCAB cases and 308 CCAB cases were included in the final analysis. We compared the number of bypass grafts and the completeness of revascularization by coronary territory. Survival and readmission for cardiac causes were monitored for up to 10 years postoperatively, with a median follow-up period of 5.9 years.

Results: On average, the patients undergoing OPCAB received significantly fewer distal anastomoses than did those undergoing CCAB (mean $\pm$ standard deviation, 2.6 ± 0.9 vs 3.0 ± 1.0 , $P < .0001$). The circumflex territory was the most likely territory to be ungrafted during OPCAB in patients with angiographically significant obstruction ($P = .0006$). The frequency of complete revascularization was significantly different between the 2 groups (OPCAB, 79.2% vs CCAB, 88.3%; $P = .0002$). The OPCAB group had a significantly greater rate of total arterial grafting (OPCAB, 66.6% vs CCAB, 49.7%; $P = .0001$). No difference was seen in 8-year survival or freedom from cardiac cause hospital readmission between the 2 groups.

Conclusions: Despite receiving fewer distal anastomoses and the decreased frequency of complete revascularization, OPCAB and CCAB techniques produced comparable results. (J Thorac Cardiovasc Surg 2013;145:992-8)

Incomplete revascularization at coronary artery bypass grafting compromises patient outcomes. In 1981, Buda and colleagues¹ reported a 5-year survival of 69% in patients incompletely revascularized vs 84% in those completely revascularized. This finding has been reiterated in several studies and selected patient populations.²⁻⁴ Scott and colleagues⁵ reported that incomplete revascularization was an independent risk factor for late mortality with a 20-year survival of 42% to 44% vs 75% for those completely revascularized. Complete revascularization has been defined as bypass grafting of all major coronary arteries with significant flow-compromising coronary

atherosclerotic lesions. Although the precise definition of complete revascularization varies in published studies,^{1,6-8} complete revascularization is obtained when the ratio of the number of distal anastomoses to the number of graftable vessels is 1 or more. Patients are categorized as having a number (usually ranging from 1 to 6) of graftable vessels based on the biplane angiographic finding of vessels with a 60% to 70% reduction in diameter with a distal vessel that appears suitable for grafting (minimum 1-mm diameter). Some investigators do not require all obtuse marginal and diagonal branches with critical proximal disease to be bypassed to be classified as meeting the revascularization standards.¹⁻³

Off-pump coronary artery bypass grafting (OPCAB) was first performed before cardiopulmonary bypass capability and then was reintroduced in the early 1980s as an alternative to conventional coronary artery bypass grafting (CCAB). There are many iterations of OPCAB; however, the current tenets are the performance of coronary artery bypass grafts by way of a full midline sternotomy on the non-arrested heart with the use of an external stabilizing device. OPCAB is available in some form in most cardiac centers in North America, with many centers preferentially using the OPCAB technique, resorting to CCAB only when a patient's hemodynamics necessitate cardiopulmonary bypass. Much early outcome data have been published to support the

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Abbreviations and Acronyms

CCAB = conventional coronary artery bypass grafting

OPCAB = off-pump coronary artery bypass grafting

safety of this procedure, with early morbidity and mortality rates equal to, or less than, those experienced by CCAB patients.

Increasing data, however, have identified that OPCAB patients are, on average, receiving significantly fewer grafts per patient than CCAB patients.⁸⁻¹⁰ A recent study of propensity matched OPCAB and CCAB patients demonstrated once again that OPCAB patients receive significantly fewer distal anastomoses than do CCAB patients. When comparing the postoperative outcomes, the investigators found that although OPCAB patients were significantly less likely to experience intraoperative strokes, they were twice as likely to require readmission for cardiac events or coronary revascularization.¹⁰ Another study with patients randomly assigned to OPCAB or CCAB found the OPCAB group had a greater frequency of incomplete revascularization, worse composite outcomes and poorer graft patency 1 year postoperatively.⁸ Synnergren and colleagues⁶ reported that the OPCAB vs CCAB technique was not associated with any difference in long-term outcomes after adjusting for incomplete revascularization but that the increased incidence of incomplete revascularization with OPCAB was associated with greater long-term mortality. Fewer reports have indicated that the OPCAB patients are receiving a similar number of grafts and have a similar frequency of complete revascularization as the CCAB cohort.^{7,11,12} The reports of similar numbers of bypass grafts being performed in OPCAB vs CCAB cohorts were mainly from prospective randomized control trials,¹³⁻¹⁵ with the vast majority of retrospective and cohort trials identifying fewer grafts in the OPCAB patients.

Thus, we reviewed our OPCAB cases and compared them with a propensity matched series from a contemporary cohort of CCAB at a single tertiary care cardiac center to determine whether a difference exists in the frequency of complete revascularization between the 2 groups. Our secondary objective was to determine whether incomplete revascularization has any affect on early morbidity or mortality. We then linked to administrative databases to determine the late survival and freedom from cardiac cause hospital readmission up to 10 years postoperatively.

METHODS

The Capital District Health Authority ethics review committee on human research approved the research protocol. The requirement to obtain informed consent was waived under Section 2.1c of the Tri-Council Policy Statement.

Patient Selection

A retrospective analysis of our OPCAB cohort was performed (January 1, 1997, to June 30, 2003). Patients were selected for OPCAB technique using subjective criteria that included consideration of the angiographic appearance of the target vessels, location of the target vessels, status of the ascending aorta, ventricular systolic function, comorbidities, and patient preference. A CCAB cohort was assembled from a concurrent group of patients undergoing conventional, non-redo, isolated coronary artery bypass grafting. The inclusion criteria also included the patient being a resident of Nova Scotia and eligible for provincial medical insurance to allow for long-term outcome evaluation. A single surgeon (C.H.F.), who was unaware of the intervention, reviewed and scored the number of graftable vessels (range, 1–7) for all potential OPCAB and CCAB cases. The scored OPCAB and CCAB patients were then propensity matched using all variables listed in Table 1, including disease burden (number of diseased vessels according to Society of Thoracic Surgeons database criteria), risk factors known to affect perioperative outcome, and surgeon. The in-hospital clinical data were obtained from the Maritime Heart Center Cardiac Surgery Registry Database.

Definition of Graftable Vessels

Vessels were categorized as graftable (range, 1–7) by the independent observer (cardiac surgeon, C.H.F.) scoring the angiograms, if the vessel had a 70% or greater reduction in diameter by biplane angiography, the vessel distal to the obstruction was 1.0 mm or greater in diameter, the vessel was accessible (ie, no circumferential calcification), and if the vessel extended sufficiently beyond the atrioventricular groove for surgical access.

Definition of Complete Revascularization

Complete revascularization depended on the scoring of graftable vessels on the angiogram by the independent observer (cardiac surgeon, C.H.F.). Complete revascularization was defined according to the diseased territory (right coronary artery, left anterior descending artery, or circumflex artery) and graftability. If 1 or more diseased territories with a graftable vessel did not receive at least 1 graft, the case was coded as incompletely revascularized. Significant left main disease was classified as 2 diseased territories if the distal vessels were appropriate targets.

Operative Technique

In all cases, a standard median sternotomy was performed. The choice of conduits and construction of composite grafts was by surgeon preference. Before use, the arterial conduits were treated with either a papaverine solution or a solution of nitroglycerin and verapamil. Patients were routinely anticoagulated in all cases. Heparin was given at a dose of 200 IU/kg in the OPCAB cases. In the CCAB cases, heparin was given at a dose of 300 IU/kg to achieve the target activated clotting time of greater than 450 seconds. Anticoagulation was routinely reversed with protamine sulphate at the end of the procedure in all patients.

The technique of OPCAB used at our institution involves placement of posterior pericardial wall traction sutures. One of 2 stabilizing systems was used to immobilize the target vessel, either the suction stabilizer, Octopus (I or II; Medtronic, Minneapolis, Minn) or the compression stabilizer, CorVasc (CoroNeo, Montreal, Ontario, Canada). A variety of techniques was used to maintain adequate visualization during the anastomoses, including a blower/mister device (Medtronic DLP; Medtronic, Grand Rapids, Mich), bulldog clamps applied proximally (and rarely distally) on the target coronary artery, intraluminal shunt or vessel occluders, or pericoronary silastic loops. The pharmacologic interventions were minimal with blood pressure support in the form of phenylephrine or neosynephrine boluses or inotropic infusions. We do not routinely administer β -blockers for rate control. Occasionally, epicardial pacing wires were established to pace the heart throughout the procedure to maintain cardiac output in the event of hemodynamically significant bradycardia.

TABLE 1. Preoperative characteristics of propensity matched OPCAB and CCAB cases

Characteristic	Matched		P value
	OPCAB (n = 308)	CCAB (n = 308)	
Age (y)	63.5 ± 10.6	62.7 ± 10.6	.37
Female gender	78 (25.3)	84 (27.3)	.58
Ejection fraction <40%	15 (4.9)	13 (4.2)	.70
NYHA class IV	115 (37.3)	115 (37.3)	.99
Diabetes	85 (27.6)	82 (26.6)	.79
MI within 21 d	26 (8.4)	27 (8.8)	.89
PVD	42 (13.6)	48 (15.6)	.49
CVD	39 (12.7)	38 (12.3)	.90
COPD	36 (11.7)	43 (14.0)	.40
Renal failure (creatinine >176 µmol/L)	11 (3.6)	12 (3.9)	.83
Urgent surgery	26 (8.4)	27 (8.8)	.89
Diseased territories			
Single	30 (9.7)	27 (8.8)	.79
Double	103 (33.4)	98 (31.8)	
Triple	175 (56.8)	183 (59.4)	
Left main stenosis >50%	40 (13.0)	39 (12.7)	.90
Graftable vessels (n)			
1	24 (7.8)	19 (6.2)	.67
2	75 (24.4)	65 (21.1)	
3	123 (39.9)	133 (43.2)	
4	65 (21.1)	73 (23.7)	
≥5	21 (6.8)	18 (5.8)	
Median (IQR)	3 (2–4)	3 (2–4)	.32
Mean (SD)	3.0 (1.0)	3.0 (1.0)	

Data presented as mean ± standard deviation or numbers, with percentages in parentheses, unless otherwise noted. OPCAB, Off-pump coronary artery bypass grafting; CCAB, conventional coronary artery bypass grafting; NYHA, New York Heart Association; MI, myocardial infarction; PVD, peripheral vascular disease; CVD, cerebrovascular disease; COPD, chronic obstructive pulmonary disease; IQR, interquartile range; SD, standard deviation.

In the CCAB patients, cardiopulmonary bypass was used in a standard fashion, with cannulation of the ascending aorta and 2-stage venous cannulation through the right atrium. A single aortic crossclamp was applied during cardiopulmonary bypass, and the mean arterial pressure was maintained at 50 mm Hg to 60 mm Hg. The body temperature was allowed to drift to a nadir of 32°C. Cold-blood cardioplegia (1:4 blood/crystalloid ratio with maximal potassium concentration of 22 mEq/L) was intermittently delivered antegrade through the aortic root whenever possible. Cardioplegia was delivered retrograde in a few cases, when indicated. Blood conservation techniques were limited to the use of nonhemic prime, the use of open cardiectomy suction, and retransfusion of all contents of the oxygenator at the end of cardiopulmonary bypass. Postoperatively, we routinely used nonhemic volume expanders.

Conversion Patients

Patients who were converted from OPCAB were those patients who were intended for OPCAB but, because of hemodynamic instability, ischemia, or rhythm disturbance, did not tolerate the positioning required for an off-pump revascularization procedure. The OPCAB conversion patients were those patients who were converted to CCAB at any point during the procedure, either before beginning grafting or after 1 or more anastomoses had been completed. The conversion patients were analyzed in an intent-to-treat manner.

Composite Early Morbidity

We pooled the perioperative complications to create a single composite morbidity variable. The constituent complications included mortality, cerebrovascular accident, perioperative myocardial infarction, mediastinitis, intra-aortic balloon pump placement, reoperation for bleeding, and reoperation for graft occlusion.

Long-Term Survival and Readmission

Late outcomes captured included all-cause mortality and readmission to the hospital for acute coronary syndrome, heart failure, or repeat coronary revascularization (surgical or catheter-based intervention). The clinical data were linked to the mortality data from the provincial vital statistics database and postoperative readmission data from the Canadian Institute for Health Information discharge abstract database, using the *International Classification of Disease*, 9th revision (fiscal years, 1997–2000) and *International Classification of Disease*, 10th revision (fiscal years, 2001–2003) codes (Appendix 1).

The longitudinal databases are housed by the Population Health Research Unit, Department of Community Health and Epidemiology, Dalhousie University Faculty of Medicine (Halifax, Nova Scotia, Canada). Longitudinal data were available to March 31, 2008 for all cardiac surgery patients in the present study who resided in Nova Scotia at the time of surgery and were eligible for provincial medical insurance.

Statistical Analysis

The clinical characteristics of each group were examined univariately. Continuous variables were compared using a 2-tailed *t*-test or Wilcoxon rank sum test, and categorical variables were analyzed using a chi-square test or Fisher's exact test.

A nonparsimonious propensity score model was developed to calculate the predicted probability of receiving OPCAB vs CCAB. The candidate variables for model building included those with chi-square *P* value < .25 and additional variables deemed clinically important regardless of the univariate *P* value. If the variance inflation factor exceeded 2.5, a candidate variable was removed from the model to reduce multicollinearity.

The propensity score was used to match the OPCAB cases 1 to 1 with the CCAB cases, and the outcomes were compared in the matched groups. Matching was performed using an algorithm that proceeded sequentially from a 5-digit to a 1-digit match on the propensity score, without replacement.¹⁶

For the matched groups of OPCAB and CCAB patients, the in-hospital outcomes were compared using the chi-square test or Fisher's exact test. Using Kaplan-Meier analysis, midterm survival and freedom from cardiac readmission were examined in the matched groups. Statistical analysis was performed using SAS, version 8.2 (SAS Institute, Cary, NC).

RESULTS

Patient Selection

A total of 411 patients requiring coronary artery bypass grafting from January 1, 1997, to June 30, 2003 at the Queen Elizabeth II Health Sciences Center, Halifax, were revascularized using the OPCAB technique. During this same interval, 5037 conventional CCAB cases were performed. Of the 411 OPCAB patients, 340 met the inclusion criteria for the present study. The CCAB cohort was assembled from 874 patients randomly selected from a concurrent group of 5037 CCAB patients. After strict propensity matching, the OPCAB patients were matched 1 to 1 with the CCAB patients, with a net of 308 patients per group.

Demographics

The patients were comparable between the 2 groups for the variables for which they had been matched (Table 1). The number of male patients in the matched cohorts was similar (OPCAB, 75% [230/308]; CCAB, 73% [224/308]). No significant differences were found between the patient groups with the respect to other morbidities known to influence perioperative mortality, including the prevalence of diabetes mellitus, peripheral vascular disease, and acute renal failure (Table 1).

Operative Details

In-hospital mortality was similar in the OPCAB cohort (1.3% [4/308]) and CCAB cohort (1.0% [3/308]). The conversion rate from OPCAB to CCAB was 12% (37/308). The mortality rate for the patients converted to CCAB was 5.4% (2/37), and it was 0.7% (2/271) for the patients not undergoing conversion. Despite equivalent numbers of graftable vessels, the OPCAB patients received a significantly different number of grafts than the CCAB patients ($P = .0001$; Table 2). The average number of distal anastomoses in the OPCAB cohort was significantly lower than that in the CCAB cohort (2.6 ± 0.9 vs 3.0 ± 1.0 , $P < .0001$). The OPCAB patients tended to receive single and double bypass grafts at a greater frequency, and the CCAB patients tended to receive triple and quadruple bypass grafts at a greater frequency. Internal mammary artery use was no different between the OPCAB and CCAB patients (Table 2). Significantly more OPCAB patients were revascularized with a total arterial strategy (66.6%) than were the CCAB patients (49.7%; $P = .0001$; Table 2).

Revascularization Completeness (Determined by an Independent Observer)

When the frequency of complete revascularization was calculated for each cohort, a significant difference was found in the rate of complete revascularization, with 244 (79.2%) of 308 OPCAB patients completely revascularized vs 272 (88.3%) of 308 CCAB patients ($P = .002$). In the OPCAB group, 33 (10.7%) of 308 graftable circumflex arteries were not bypasses vs 11 (3.6%) of 308 in the CCAB cohort ($P = .0006$). The left anterior descending and right coronary artery territories were revascularized at similar rates in the OPCAB and CCAB populations (Table 2). Patients with more than 3 graftable vessels had significantly lower rates of complete revascularization in the OPCAB cohort (81.4% [70/86]) than in the CCAB patients (94.5% [86/91]; $P = .01$).

Early Versus Late Operative Experience: Frequency of Complete Revascularization

Complete revascularization occurred with equal frequency in our surgical population regardless of their place in our experience (early OPCAB experience, first 50 cases,

TABLE 2. Technical graft details and completeness of revascularization by territory in matched groups

Variable	OPCAB (n = 308)	CCAB (n = 308)	P value
Distal anastomoses			.0001
1	34 (11.0)	14 (4.6)	
2	114 (37.0)	83 (27.0)	
3	115 (37.3)	127 (41.2)	
4	40 (13.0)	61 (19.8)	
≥5	5 (1.6)	23 (7.5)	
Graft conduit			
SVG	103 (33.4)	155 (50.3)	.0001
LIMA	295 (95.8)	289 (93.8)	.28
RIMA	84 (27.3)	82 (26.6)	.86
BIMA	79 (25.6)	77 (25.0)	.85
Radial	65 (21.1)	78 (25.3)	.21
Total arterial grafting	205 (66.6)	153 (49.7)	.0001
Territories with complete revascularization			
LAD	304 (98.7)	304 (98.7)	1.0
Cx	275 (89.3)	297 (96.4)	.0006
RCA	276 (89.6)	285 (92.5)	.2

Data presented as numbers, with percentages in parentheses. OPCAB, Off-pump coronary artery bypass grafting; CCAB, conventional coronary artery bypass grafting; SVG, saphenous vein graft; LIMA, left internal mammary artery; RIMA, right internal mammary artery; BIMA, bilateral internal mammary arteries; LAD, left anterior descending artery; Cx, circumflex; RCA, right coronary artery.

82%; middle, 77.9%; or late in the series, last 50 cases, 82%; $P = .71$).

Early Morbidity

The early morbidities experienced by both groups were similar (Table 3). The composite morbidity outcome was similar in the OPCAB cohort (15 cases [4.9%]) and the CCAB cohort (13 cases [4.2%]; $P = .70$). OPCAB and CCAB were associated with similar rates of transfusion (26/308 vs 37/308; $P = .14$). The hospital length of stay was similar between the 2 groups. The median length of hospital stay for the OPCAB patients was 6 days (interquartile range, 5–8 days) vs 6 days (interquartile range, 5–8 days) for the CCAB group.

Long-Term Survival and Freedom From Cardiac Readmission

The patients were followed up for up to 10 years postoperatively, with a median follow-up time of 5.9 years. All-cause mortality, including operative deaths, was similar at 5 and 8 years ($P = .89$; Figure 1). The 5-year survival in the matched OPCAB and CCAB cohorts was 90.1% (95% confidence interval [CI], 86.8%–93.5%) and 90.8% (95% CI 87.5%–94%), respectively. At 8 years postoperatively, survival was 80.8% (95% CI, 75.3%–86.4%) in the OPCAB cohort and 78.7% (95% CI, 73.6%–83.8%) in the CCAB cohort.

TABLE 3. Early postoperative morbidity in matched groups

Morbidity	OPCAB (n = 308)	CCAB (n = 308)	P value
Composite outcome	15 (4.9)	13 (4.2)	.70
Mortality	4 (1.3)	3 (1.0)	
Cerebrovascular accident	6 (2.0)	1 (0.3)	
Perioperative MI	3 (1.0)	3 (1.0)	
Mediastinitis	1 (0.3)	1 (0.3)	
Intra-aortic balloon pump	4 (1.3)	4 (1.3)	
Bleeding	4 (1.3)	2 (0.6)	
Graft occlusion	0 (0.0)	1 (0.3)	
Transfusion	26 (8.4)	37 (12.0)	.14
Pneumonia	9 (2.9)	11 (3.6)	.65

Data presented as numbers, with percentages in parentheses. OPCAB, Off-pump coronary artery bypass grafting; CCAB, conventional coronary artery bypass grafting; MI, myocardial infarction.

Long-term freedom from cardiac readmission, including readmission for acute coronary syndrome, congestive heart failure, or revascularization, was similar between the 2 groups ($P = .72$; Figure 2). Freedom from cardiac readmission at 5 years was 77.2% (95% CI, 72.4%–82.0%) in the OPCAB cohort and 73.8% (95% CI, 68.8%–78.8%) in the CCAB cohort. At 8 years, freedom from cardiac readmission was 68.3% (95% CI, 62.3%–74.3%) in the OPCAB cohort and 68.1% (95% CI, 62.5%–73.6%) in the CCAB cohort.

DISCUSSION

Completeness of Revascularization

An increasing number of recent reports of OPCAB outcomes have identified that, without stratifying the number of graftable vessels, diffuseness of disease, or myocardium

at risk, the number of grafts performed on OPCAB patients are consistently fewer than those performed on CCAB patients. No retrospective reports have shown significantly greater numbers of grafts performed in the OPCAB cohort, and only a handful of retrospective trials have shown an equivalent number of grafts performed in OPCAB vs CCAB populations. In contradistinction to our findings, some prospective series are reporting more grafts on average in OPCAB patients than in CCAB patients. Cartier and colleagues¹¹ reported a prospective series of 300 OPCAB cases accrued by 1 surgeon. In that series, the average number of grafts performed in the OPCAB cohort actually exceeded the average number of grafts performed in the CCAB patients (2.92 ± 0.8 vs 2.84 ± 0.6 grafts per patient). It is conceivable that there might be some offsetting biases in the prospective trials that influenced the rates of complete revascularization; therefore, these studies might not be a valid reflection of real-life practice. Several groups first published retrospective trials reporting, on average, significantly fewer grafts performed in the OPCAB cohort and subsequently published randomized trials in which the number of grafts performed in each group was identical.^{14,17–21} Because of the possibility of this bias effect, we believe that the real world experience might more accurately reflected by the results of retrospective reviews. The reality might be that, in many surgeons' practice, the OPCAB patients are more frequently subject to incomplete revascularization than are the CCAB patients. To remove this potential bias and the potential bias of preferentially selecting patients with fewer graftable vessels for OPCAB, the present study was designed as a propensity matched, retrospective control trial on the basis of the number of graftable vessels.

FIGURE 1. Long-term survival after coronary artery bypass grafting in propensity matched cohorts undergoing conventional coronary artery bypass grafting (CCAB, solid red line) or off-pump coronary artery bypass grafting (OPCAB, dashed line). Postoperative survival was comparable in the 2 groups 5 and 8 years postoperatively. CI, Confidence interval.

FIGURE 2. Long-term freedom from cardiac cause readmission to hospital after coronary artery bypass grafting in propensity matched cohorts undergoing conventional coronary artery bypass grafting (CCAB, solid red line) or off-pump coronary artery bypass grafting (OPCAB, dashed line). Postoperative freedom from cardiac cause readmission was similar in the 2 groups 5 and 8 years postoperatively. *CI*, Confidence interval.

In our study, OPCAB patients with the same number of graftable vessels received on average fewer bypass grafts than did the CCAB patients. The difference in the average number of grafts per patient translated into a greater rate of incomplete revascularization for the OPCAB patients than for the CCAB patients. The circumflex territory was incompletely revascularized in a greater proportion of OPCAB than CCAB patients and accounted for the difference in the rates of complete revascularization. Despite the differences in the rates of complete revascularization, the early mortality and morbidity rates in our cohort are similar to previous data,^{8,10,14} and no differences were found in long-term survival or readmission to hospital for cardiac-related causes. Failure to graft the circumflex might not be important to the long-term outcome, as suggested by these results and previously published data.³ Internal mammary artery use was similar between the OPCAB and CCAB cohorts in our study, likely because all cases were non-redo cases. The greater frequency of total arterial grafting in the OPCAB cohort reflected the individual practice patterns of some of the surgeons performing the OPCAB cases, who, regardless of OPCAB or CCAB, have the greatest rates of total arterial grafting in our surgical group (data not shown). The significantly greater rates of total arterial grafting in the OPCAB cohort might have confounded the effect of incomplete revascularization because there might be a survival benefit with total arterial grafting.²² It is also possible that the effect of incomplete revascularization might yet be occult and that the curves will diverge as patients move further from the original surgery and the vein grafts begin the steep portion of their attrition.

Study Limitations

The frequency of complete revascularization achieved in our OPCAB and CCAB cohorts might have been influenced by our relative experience with each technique. At our center, the CCAB technique is used for most cases, and the OPCAB technique is used for only a few cases. OPCAB was first performed at our center in 1996, and the data we have presented included our early OPCAB experience. We did not find an increase in the rates of complete revascularization in the late vs early OPCAB experience; thus, a learning curve could not fully account for the fewer grafts performed in the OPCAB patients. However, because the completeness of revascularization in the OPCAB patients might have been influenced by previous experience with the technique, these results will be of greatest relevance to surgeons and institutions that primarily use the CCAB technique or are gaining experience with OPCAB. The frequency of complete revascularization we have reported might not reflect what can be achieved by highly experienced OPCAB surgeons. From the present retrospective trial, it is difficult to determine the significance of the ungrafted territory for a number of reasons. First, it was impossible to determine myocardial viability in the territory left ungrafted, because myocardial viability studies were available for only a small minority of the patients; thus, the significance of a reduced number of grafts in the OPCAB cohort was impossible to predict. Likewise, we did not use a myocardium at risk score, which is a potentially valuable tool to aid in determining the true significance of the nonrevascularized territory because there is a recognized hierarchy of effect, depending on which vessels are left

ungrafted and how much myocardium is at risk. Another problem with the present trial was in determining vessel graftability. There has been a scoring system of the diffuseness of disease reported that would allow for greater finesse in describing the degree of disease in the vessels, another factor that can affect patient morbidity and mortality.²³

CONCLUSIONS

When matched for disease burden, OPCAB patients, on average, received fewer distal anastomoses than did CCAB patients. Although OPCAB patients were less frequently completely revascularized than CCAB patients, this did not translate into any difference in long-term survival or freedom from readmission to hospital for cardiac-related causes.

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APPENDIX 1

Appendix of codes used to define postcoronary artery bypass grafting hospital admission for acute coronary syndrome, heart failure, and repeat coronary revascularization.

Fiscal years 1997–2000

Acute coronary syndrome: *International Classification of Diseases, 9th revision, Clinical Modification* (ICD-9-CM) codes 410.0–411.89

Heart failure: ICD-9-CM codes 428.0–428.9

Coronary revascularization: ICD-9-CM codes 36.01–36.03, 36.05–36.09, 36.01–36.2

Fiscal years 2001–2003

Acute coronary syndrome: *International Classification of Diseases, 10th revision, Canada* (ICD-10-CA) codes I20.0, I21.0–I21.9, I22.0–I22.9

Heart failure: ICD-10-CA codes I50.0–I50.9

Coronary revascularization: Canadian Classification of Health Interventions codes 1IJ.50, 1IJ.54, 1IJ.57, 1IJ.76, 1IJ.80, 1IL.35