

Early and Midterm Outcome after Off-Pump Coronary Artery Bypass Grafting in Patients with Left Ventricular Dysfunction

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ABSTRACT

Background: The purpose of this study was to define the early outcome and the potential for midterm survival in patients with left ventricular dysfunction (LVD) who undergo off-pump coronary artery bypass (OPCAB) and to compare these results with those of conventional coronary artery bypass grafting (CABG).

Methods: Medical records of patients with LVD (n = 732) between January 1998 and March 2002 were retrospectively reviewed. There were 523 patients with moderate LVD (ejection fraction, 30%-50%; 463 CABG versus 60 OPCAB) and 209 patients with severe LVD (ejection fraction, <30%; 136 CABG versus 73 OPCAB). Midterm survival data (mean follow-up, 2.3 years) were obtained from the National Death Index. Groups were compared by multivariate Cox proportional hazard models, and Kaplan-Meier curves were plotted.

Results: CABG patients had lower European System for Cardiac Operative Risk Evaluation values (5.3 versus 7.2 and 8.0 versus 9.6 in moderate and severe LVD subgroups, respectively; $P < .001$). There were no differences (OPCAB versus CABG) in 30-day mortality (3.3% versus 1.9%, moderate LVD group, $P = .366$; 6.8% versus 4.4%, severe LVD group, $P = .521$), length of stay (9.3 versus 8.6 days, moderate LVD group, $P = .683$; 11.9 versus 11.8 days, severe LVD group, $P = .423$), and postoperative complications (13.3% versus 11.0%, moderate LVD group, $P = 0.663$; 16.4% versus 20.6%, severe LVD group, $P = .581$). Successful coronary bypass in patients with severe LVD was associated with 68.2% and 66.2% actuarial 48-month survival rates for the CABG and OPCAB patients, respectively ($P = .336$), and these rates rose to 86.0% and 82.9% in patients with moderate LVD ($P = .121$). When CABG patients with moderate

LVD were considered the reference group, the adjusted hazard ratio of OPCAB patients with moderate LVD for midterm mortality was 1.32 (95% confidence interval, 0.61-2.87; $P = .481$). CABG and OPCAB patients with severe LVD had the same adjusted hazard ratio of 1.86, and this figure was statistically significant compared with the value for the reference group ($P = .011$ and $P = .039$, respectively).

Conclusions: Patients with LVD can derive midterm benefit from coronary bypass. OPCAB in higher-risk patients had early and midterm outcomes similar to those of CABG.

INTRODUCTION

Patients with left ventricular dysfunction (LVD) are known to be at higher risk of morbidity and mortality after surgical coronary revascularization [Milano 1993, Bouchart 2001, Carr 2002, DeRose 2004]. LVD of ischemic etiology is associated with an approximately 40% 5-year survival rate with medical treatment versus 60% with conventional coronary artery bypass grafting (CABG) with cardiopulmonary bypass [O'Connor 2002]. In addition, off-pump coronary artery bypass (OPCAB) has been shown to provide functional improvement with favorable operative mortality in the growing group of patients with LVD who undergo surgical revascularization [Arom 2000, Meharwal 2002, Al Ruzzeh 2003]. It has also been demonstrated that midterm survival results have been improved in high-risk patients with OPCAB after the advent and use of innovative techniques [Toumpoulis 2004c]. However, there is no consensus on which of the 2 techniques is superior with respect to LVD and midterm survival.

The purpose of this study was to define early outcome and the potential for midterm survival in patients with OPCAB and LVD and to compare these results with those for the CABG group. We analyzed a consecutive series of patients with moderate and severe LVD at a single institution from 1998 to 2002 to include OPCAB patients operated on with the use of innovative techniques.

MATERIALS AND METHODS

Patients

Our study consisted of 732 consecutive patients who underwent isolated CABG at St. Luke's-Roosevelt Hospital Center, which is affiliated with Columbia University College

Presented at the Seventh Annual Meeting of the International Society for Minimally Invasive Cardiothoracic Surgery, London, UK, June 23-26, 2004.

Received July 14, 2004; received in revised form September 11, 2004; accepted September 13, 2004.

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Table 1. Preoperative Characteristics of Coronary Artery Bypass Grafting (CABG) and Off-Pump Coronary Artery Bypass (OPCAB) Patients with Moderate Left Ventricular Dysfunction (Left Ventricular Ejection Fraction 30%-50%)*

Variable	CABG (n = 463)	OPCAB (n = 60)	P
Age (mean ± SD), y	64.5 ± 10.5	69.4 ± 10.0	.001
Female, n (%)	138 (29.8)	25 (41.7)	.075
Vessels involved			
One-vessel disease, n (%)	6 (1.3)	1 (1.7)	.576
Two-vessel disease, n (%)	77 (16.6)	14 (23.3)	.206
Three-vessel disease, n (%)	380 (82.1)	45 (75.0)	.217
Unstable angina, n (%)	289 (62.4)	39 (65.0)	.777
CCS angina class, mean ± SD	3.5 ± 0.7	3.6 ± 0.7	.699
Previous MI, n (%)	172 (37.1)	5 (8.3)	<.001
Transmural MI, n (%)	183 (39.5)	22 (36.7)	.779
Additional previous MI, n (%)	77 (16.6)	9 (15.0)	.854
Urgency of operation			
Emergency, n (%)	57 (12.3)	2 (3.3)	.048
Urgent, n (%)	265 (57.2)	35 (58.3)	.891
Elective, n (%)	141 (30.5)	23 (38.3)	.237
Previous cardiac operation, n (%)	20 (4.3)	17 (28.3)	<.001
Previous PCI, n (%)	66 (14.3)	19 (31.7)	.001
Ejection fraction, %	42.2 ± 6.9	41.3 ± 7.4	.329
Hemodynamic instability, n (%)	12 (2.6)	2 (3.3)	.669
Shock, n (%)	1 (0.2)	0 (0)	.999
NTG 24 h before operation, n (%)	68 (14.7)	13 (21.7)	.183
Thrombolysis, n (%)	29 (6.3)	4 (6.7)	.783
Myocardial rupture, n (%)	2 (0.4)	0 (0)	.999
Current CHF, n (%)	67 (14.5)	20 (33.3)	.001
Past CHF, n (%)	44 (9.5)	7 (11.7)	.642
PVD, n (%)	101 (21.8)	20 (33.3)	.052
Body mass index, mean ± SD	19.9 ± 4.3	21.0 ± 4.7	.060
Hypertension, n (%)	366 (79.0)	51 (85.0)	.311
LV hypertrophy, n (%)	70 (15.1)	7 (11.7)	.565
COPD, n (%)	41 (8.9)	7 (11.7)	.476
Preoperative IABP, n (%)	18 (3.9)	1 (1.7)	.712
Diabetes mellitus, n (%)	188 (40.6)	27 (45.0)	.577
Calcified aorta, n (%)	14 (3.0)	13 (21.7)	<.001
Hepatic failure, n (%)	3 (0.6)	0 (0)	.999
Renal failure, n (%)	8 (1.7)	2 (3.3)	.321
Dialysis, n (%)	5 (1.1)	1 (1.7)	.520
Immune deficiency, n (%)	9 (1.9)	2 (3.3)	.366
Smoking past 2 weeks, n (%)	95 (20.5)	9 (15.0)	.391
Smoking last year, n (%)	49 (10.6)	4 (6.7)	.494

*CCS indicates Canadian Cardiovascular Society; MI, myocardial infarction; PCI, percutaneous coronary intervention; NTG, nitroglycerin; CHF, congestive heart failure; PVD, peripheral vascular disease; LV, left ventricular; COPD, chronic obstructive pulmonary disease; IABP, intraaortic balloon pump.

of Physicians and Surgeons, between January 1998 and March 2002. Data were prospectively collected during admission as part of routine clinical practice and entered into the New York State adult cardiac surgery report for the variables shown in Tables 1 to 4. Patients were divided into

2 groups according to left ventricular ejection fraction (LVEF): a moderate LVD group with LVEF between 30% and 50% and a severe LVD group with LVEF <30%. In study A, patients with moderate LVD who underwent CABG (n = 463) were compared with patients with moderate LVD who underwent OPCAB (n = 60). In study B, patients with severe LVD who underwent CABG (n = 136) were compared with patients with severe LVD who underwent OPCAB (n = 73). No specified selection criteria were used to determine which procedure, CABG or OPCAB, individual patients would receive. Selection was based on the individual surgeon's experience and preference. No randomization was involved in this study.

CABG Operation

CABG was carried out through a full sternotomy incision, with the left, right, or both internal thoracic arteries taken down in the usual fashion. Institution of cardiopulmonary bypass was achieved by cannulating the ascending aorta and right atrium. Standard bypass management included membrane oxygenators, arterial line filters, nonpulsatile flow of 2.4 L/min per square meter, and a mean arterial pressure greater than 50 mm Hg. Retrograde cardioplegia of either blood or crystalloid solution was delivered for myocardial protection of the arrested heart.

Table 2. Intraoperative Characteristics and Early Outcome in Coronary Artery Bypass Grafting (CABG) and Off-Pump Coronary Artery Bypass (OPCAB) Patients with Moderate Left Ventricular Dysfunction (Left Ventricular Ejection Fraction 30%-50%)*

	CABG (n = 463)	OPCAB (n = 60)	P
Intraoperative characteristics			
Two or more arterial grafts, n (%)	350 (75.6)	36 (60.0)	.013
Number of distal anastomoses, mean ± SD	3.6 ± 1.0	2.6 ± 0.9	<.001
Microscope use, n (%)	279 (60.3)	51 (85.0)	<.001
Early mortality and LOS			
EuroSCORE standard, mean ± SD	5.3 ± 2.6	7.2 ± 2.6	<.001
30-day mortality, n (%)	9 (1.9)	2 (3.3)	.366
In-hospital deaths, n (%)	11 (2.4)	1 (1.7)	.999
LOS (mean ± SD), d	8.6 ± 8.3	9.3 ± 8.0	.683
Major complications			
Intraoperative stroke, n (%)	6 (1.3)	2 (3.3)	.231
Over 24 hours stroke, n (%)	8 (1.7)	1 (1.7)	.999
Postoperative myocardial infarction, n (%)	1 (0.2)	0 (0)	.999
Deep sternal wound infection, n (%)	10 (2.2)	0 (0)	.614
Bleeding/reoperation, n (%)	13 (2.8)	1 (1.7)	.999
Sepsis/endocarditis, n (%)	4 (0.9)	2 (3.3)	.143
Gastrointestinal bleeding, perforation, or infarction, n (%)	6 (1.3)	1 (1.7)	.576
Renal failure/dialysis, n (%)	3 (0.6)	1 (1.7)	.387
Respiratory failure, n (%)	25 (5.4)	3 (5.0)	.999
Number of patients with major complication	51 (11.0)	8 (13.3)	.663

*LOS indicates length of stay; EuroSCORE, European System for Cardiac Operative Risk Evaluation.

Table 3. Preoperative Characteristics of Coronary Artery Bypass Grafting (CABG) and Off-Pump Coronary Artery Bypass (OPCAB) Patients with Severe Left Ventricular Dysfunction (Left Ventricular Ejection Fraction <30%)*

Variable	CABG (n = 136)	OPCAB (n = 73)	P
Age (mean ± SD), y	65.8 ± 10.0	69.9 ± 10.3	.006
Female, n (%)	35 (25.7)	20 (27.4)	.869
Vessels involved			
One-vessel disease, n (%)	0 (0)	0 (0)	.999
Two-vessel disease, n (%)	12 (8.8)	8 (11.0)	.628
Three-vessel disease, n (%)	124 (91.2)	65 (89.0)	.628
Unstable angina, n (%)	101 (74.3)	60 (82.2)	.229
CCS angina class, mean ± SD	3.7 ± 0.6	3.8 ± 0.4	.150
Previous MI, n (%)	55 (40.4)	11 (15.1)	<.001
Transmural MI, n (%)	66 (48.5)	48 (65.8)	.017
Additional previous MI, n (%)	36 (26.5)	30 (41.1)	.030
Urgency of operation			
Emergency, n (%)	21 (15.4)	25 (34.2)	.003
Urgent, n (%)	91 (66.9)	35 (47.9)	.008
Elective, n (%)	24 (17.6)	13 (17.8)	.999
Previous cardiac operation, n (%)	4 (2.9)	9 (12.3)	.013
Previous PCI, n (%)	18 (13.2)	8 (11.0)	.665
Ejection fraction, %	20.8 ± 5.0	16.1 ± 6.1	<.001
Hemodynamic instability, n (%)	7 (5.1)	11 (15.1)	.020
Shock, n (%)	2 (1.5)	3 (4.1)	.345
NTG 24 h before operation, n (%)	29 (21.3)	23 (31.5)	.131
Thrombolysis, n (%)	11 (8.1)	8 (11.0)	.614
Myocardial rupture, n (%)	0 (0)	0 (0)	.999
Current CHF, n (%)	67 (49.3)	42 (57.5)	.254
Past CHF, n (%)	49 (36.0)	21 (28.8)	.357
PVD, n (%)	43 (31.6)	18 (24.7)	.340
Body mass index, mean ± SD	21.0 ± 4.6	22.5 ± 4.6	.027
Hypertension, n (%)	107 (78.7)	48 (65.8)	.048
LV hypertrophy, n (%)	32 (23.5)	13 (17.8)	.381
COPD, n (%)	16 (11.8)	15 (20.5)	.104
Preoperative IABP, n (%)	21 (15.4)	12 (16.4)	.845
Diabetes mellitus, n (%)	71 (52.2)	30 (41.1)	.125
Calcified aorta, n (%)	13 (9.6)	18 (24.7)	.007
Hepatic failure, n (%)	1 (0.7)	0 (0)	.999
Renal failure, n (%)	5 (3.7)	5 (6.8)	.324
Dialysis, n (%)	6 (4.4)	2 (2.7)	.716
Immune deficiency, n (%)	2 (1.5)	4 (4.1)	.345
Smoking past 2 weeks, n (%)	28 (20.6)	19 (26.0)	.389
Smoking last year, n (%)	12 (8.8)	8 (11.0)	.628

*CCS indicates Canadian Cardiovascular Society; MI, myocardial infarction; PCI, percutaneous coronary intervention; NTG, nitroglycerin; CHF, congestive heart failure; PVD, peripheral vascular disease; LV, left ventricular; COPD, chronic obstructive pulmonary disease; IABP, intraaortic balloon pump.

OPCAB Operation

The OPCAB operation was usually carried out through a sternotomy incision with the left, right, or both internal thoracic arteries taken down in the usual fashion. Three deep pericardial traction stitches were placed near the left upper

and lower pulmonary veins and to the left of the inferior vena cava, thereby achieving elevation of the apex of the heart. For further assistance in providing good presentation of the target arteries on the lateral and inferior aspects of the heart, patients were placed in a gentle decubitus Trendelenburg position. Various techniques and innovations were used during the years 1998 to 2002, such as the Octopus for stabilization (Medtronic, Minneapolis, MN, USA) and others (CardioThoracic Systems, Cupertino, CA, USA), silicone elastomer vessel loops (Quest Medical, Allen, TX, USA), a DLP carbon dioxide blower (Medtronic, Grand Rapids, MI, USA), and intraluminal coronary shunts (Bio-Vascular, St. Paul, MN, USA).

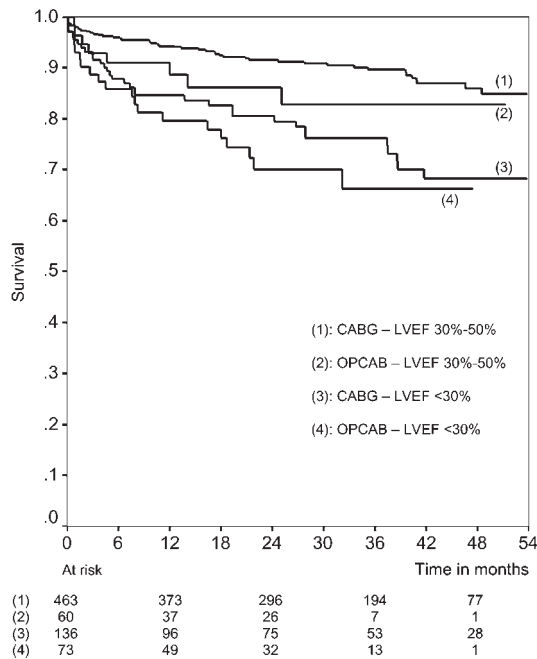
Data Analysis

Midterm patient mortality data were obtained from the United States Social Security Death Index database (<http://ssdi.genealogy.rootsweb.com>). The sensitivity of the National Death Index in identifying deaths is between 92% and 99% depending on which identifiers are available [Williams 1992]. Social Security number alone has the best accuracy of any combination of other identifiers (eg, first initial, last name, day of birth, month of birth, year of birth) with a sensitivity of 97% and a specificity of 99% [Williams 1992]. In this study we used only Social Security numbers,

Table 4. Intraoperative Characteristics and Early Outcome in Coronary Artery Bypass Grafting (CABG) and Off-Pump Coronary Artery Bypass (OPCAB) Patients with Severe Left Ventricular Dysfunction (Left Ventricular Ejection Fraction <30%)*

	CABG (n = 136)	OPCAB (n = 73)	P
Intraoperative characteristics			
Two or more arterial grafts, n (%)	97 (71.3)	38 (52.1)	.005
Number of distal anastomoses, mean ± SD	3.6 ± 0.8	3.2 ± 0.9	.007
Microscope use, n (%)	81 (59.6)	69 (94.5)	<.001
Early mortality and LOS			
EuroSCORE standard, mean ± SD	8.0 ± 2.8	9.6 ± 3.1	<.001
30-day mortality, n (%)	6 (4.4)	5 (6.8)	.521
In-hospital deaths, n (%)	7 (5.1)	5 (6.8)	.756
LOS (mean ± SD), d	11.8 ± 12.9	11.9 ± 10.3	.423
Major complications			
Intraoperative stroke, n (%)	4 (2.9)	1 (1.4)	.660
Over 24 hours stroke, n (%)	2 (1.5)	1 (1.4)	.999
Postoperative myocardial infarction, n (%)	0 (0)	0 (0)	.999
Deep sternal wound infection, n (%)	5 (3.7)	1 (1.4)	.667
Bleeding/reoperation, n (%)	7 (5.1)	0 (0)	.099
Sepsis/endocarditis, n (%)	2 (1.5)	0 (0)	.543
Gastrointestinal bleeding, perforation or infarction, n (%)	2 (1.5)	3 (4.1)	.345
Renal failure/dialysis, n (%)	3 (2.2)	4 (5.5)	.242
Respiratory failure, n (%)	13 (9.6)	8 (11.0)	.811
Number of patients with major complication	28 (20.6)	12 (16.4)	.581

*LOS indicates length of stay; EuroSCORE, European System for Cardiac Operative Risk Evaluation.



Kaplan-Meier survival curves of coronary artery bypass grafting (CABG) patients and off-pump coronary artery bypass (OPCAB) patients with either moderate or severe left ventricular dysfunction. LVEF indicates left ventricular ejection fraction.

which were available for most (99.2%) of the patients, and using the numbers allowed us to avoid using patients' names. Moreover, patients without a Social Security number (n = 6) were censored at the time of discharge from the hospital. The index was queried in September 2002, and patients not found in the index were assumed to be alive at that time.

Statistical Methods

Numerical variables are presented as mean ± SD. Discrete variables were summarized by percentages. Discrete variables were compared between groups by Fisher exact test or χ² test where appropriate. Numerical variables were compared by independent t test or Mann-Whitney U test where appropriate. For all groups compared, we generated Kaplan-Meier curves [Kaplan 1958], and for comparison we used the log-rank test. Multivariable Cox proportional hazards regression models [Cox 1972] were used to calculate hazard ratios of all groups while adjustment was made for only preoperative or for both preoperative and intraoperative factors associated with midterm mortality. The model selection was done with a backward stepwise method starting from all variables with P < .05 in univariate analyses. All analyses were performed in SPSS 11.0 (SPSS, Chicago, IL, USA). P < .05 was considered statistically significant, and all P values were 2-tailed.

RESULTS

In study A (patients with moderate LVD, or LVEF 30%-50%), OPCAB patients had a higher European System for Cardiac Operative Risk Evaluation value (EuroSCORE)

(7.2 ± 2.6 versus 5.3 ± 2.6 in CABG patients, P < .001). Preoperative characteristics of the 2 groups are shown in Table 1. There was no difference in LVEF between groups (41.3% ± 7.4% in OPCAB versus 42.2% ± 6.9% in CABG patients, P = .329). However, compared with CABG patients, OPCAB patients were older (P = .001); underwent a greater number of emergency operations (P = .048), previous cardiac operations (P < .001), and percutaneous coronary interventions (P = .001); and had higher percentages of current congestive heart failure (P = .001) and calcified aorta (P < .001). CABG patients had higher percentage of previous myocardial infarction (P < .001).

Table 2 compares type of graft, number of distal anastomoses performed, early clinical outcome, and major postoperative complications. CABG patients received more arterial grafts (2 or more arterial grafts, 75.6% versus 60.0% in OPCAB, P = .013) and more distal anastomoses (3.6 ± 1.0 versus 2.6 ± 0.9 in OPCAB, P < .001). There were no significant differences between the 2 groups in 30-day mortality (P = .366), in-hospital mortality (P = .999), length of stay (P = .683), and major postoperative complications (total number of patients with major postoperative complications, 13.3% in OPCAB versus 11.0% in CABG, P = .663). Midterm survival rates as estimated by Kaplan-Meier curves were in favor of the CABG group (actuarial 48-month survival, 86.0 ± 2.1% versus 82.9 ± 5.8% in OPCAB), but this difference was not statistically significant (P = .121) (Figure, Kaplan-Meier curves 1 and 2).

In study B (patients with severe LVD, or LVEF <30%) OPCAB patients had a higher EuroSCORE (9.6 ± 3.1 versus 8.0 ± 2.8 in CABG patients, P < .001). Preoperative characteristics of the 2 groups are shown in Table 3. There was a statistically significant difference in LVEF between the groups (16.1% ± 6.1% in OPCAB versus 20.8% ± 5.0% in CABG patients, P < .001). Compared with CABG patients, OPCAB patients were older (P = .006), had a higher body mass index (P = .027), underwent a greater number of emergency operations (P = .003) and previous cardiac operations (P = .013), and had higher percentages of transmural myocardial infarction (P = .017), more than 1 previous myocardial infarction (P = .030), hemodynamic instability (P = .020), and calcified aorta (P = .007). CABG patients had a larger number of urgent operations (P = .008), a higher percentage of previous myocardial infarction (P < .001), and a higher percentage of hypertension (P = .048).

Table 4 compares type of graft, number of distal anastomoses performed, early clinical outcome, and major postoperative complications. CABG patients received more arterial grafts (2 or more arterial grafts, 71.3% versus 52.1% in OPCAB, P = .005) and more distal anastomoses (3.6 ± 0.8 versus 3.2 ± 0.9 in OPCAB, P = .007). There were no significant differences between the 2 groups in 30-day mortality (P = .521), in-hospital mortality (P = .756), length of stay (P = .423), or major postoperative complications (total number of patients with major postoperative complications, 16.4% in OPCAB versus 20.6% in CABG, P = .581). Midterm survival rates estimated by Kaplan-Meier curves were in favor of the CABG group (actuarial 48-month survival, 68.2% ± 5.0% versus 66.2% ± 6.7% in OPCAB), but

Table 5. Adjusted Hazard Ratios for Midterm Mortality after Surgical Revascularization*

Group	Adjusted Hazard Ratio†	95% Confidence Interval	P
CABG, LVEF 30%-50%	1.00	Reference	—
OPCAB, LVEF 30%-50%	1.32	0.61-2.87	.481
CABG, LVEF <30%	1.86	1.16-3.01	.011
OPCAB, LVEF <30%	1.86	1.03-3.35	.039

*CABG patients with left ventricular ejection fraction 30%-50% were considered as the reference group. CABG, coronary artery bypass grafting; LVEF, left ventricular ejection fraction; OPCAB, off-pump coronary artery bypass

†Adjusted for preoperative characteristics.

this difference was not statistically significant ($P = .336$) (Figure, Kaplan-Meier curves 3 and 4).

In this study we performed 2 multivariable Cox regression analyses, and in both analyses CABG patients with moderate LVD were considered the reference group (hazard ratio, 1.00). In the first multivariable Cox proportional hazard model, the compared groups were adjusted only for preoperative factors (Table 5). For OPCAB patients with moderate LVD the adjusted hazard ratio for midterm mortality was 1.32 (95% confidence interval, 0.61-2.87) and was not statistically significant compared with the ratio for the reference group ($P = .481$). CABG patients and OPCAB patients with severe LVD had the same adjusted hazard ratio of 1.86. This value was statistically significant compared with the ratio for reference group ($P = .011$ and $P = .039$, respectively). In the second multivariable Cox proportional hazard model the compared groups were adjusted for both preoperative and intraoperative factors (Table 6). In this analysis the adjusted hazard ratio of OPCAB patients with moderate LVD was 0.69 (95% confidence interval, 0.28-1.70) and was not statistically significant compared with the value for the reference group ($P = .418$). CABG patients with severe LVD had almost the same hazard ratio as in the first multivariable Cox proportional hazard model. This value was statistically significant compared with the value for the reference group ($P = .012$). However, OPCAB patients with severe LVD had an adjusted hazard ratio of 1.21 (95% confidence interval, 0.63-2.30). This value was not statistically significant compared with the value for the reference group ($P = .565$).

DISCUSSION

Multiple reports have shown that OPCAB surgery reduces early morbidity associated with cardiopulmonary bypass. However, the major question regarding the efficacy of OPCAB is whether the need to contend with heart motion and more blood in the operative field compromises the quality of distal anastomoses and consequently results in less durable or less complete revascularization affecting midterm outcome. There is evidence that despite the fewer bypass grafts used in OPCAB patients, this group does not have a lower survival rate or increased number of ischemic events at 4 years [Sabik 2004]. It is interesting that in a large study in

the state of New York in which early and midterm results were compared for all patients with CABG and OPCAB with sternotomy from 1997 to 2000, investigators found that CABG patients had better 3-year rates of survival and freedom from revascularization than OPCAB patients [Racz 2004]. However, the survival benefit from CABG procedures was no longer present in the last 2 years of that study. In addition, we found in a previous study that midterm survival results improved in the OPCAB group after use of innovative techniques in recent years [Toumpoulis 2004c].

The increasing prevalence of referral of patients with moderate to severe LVD of ischemic etiology for surgical revascularization is the result of widespread use of nonsurgical interventions such as thrombolysis and percutaneous coronary intervention, which may delay the surgical procedure until coronary arteriosclerosis is more extensive and LVD more severe. This group of patients is known to be at higher risk of early and long-term mortality [Bouchart 2001, Carr 2002, DeRose 2004]. The use of OPCAB technique in patients with LVD seems to be particularly attractive because of avoidance of the deleterious effects of cardiopulmonary bypass. It has been confirmed that OPCAB is an alternative to CABG in patients with moderate or severe LVD with comparable early outcome [Moshkovitz 1997, Arom 2000, Tugtekin 2000, Shennib 2002, Al Ruzzeah 2003, Jasinski 2003]. However, there is a paucity of midterm results of comparisons of the efficacy of OPCAB with that of CABG in this high-risk population.

This retrospective comparative study demonstrated that OPCAB technique provided midterm results similar to those of CABG operations. In the moderate LVD group the estimated 48-month survival rate was 86% in CABG patients versus 83% in OPCAB patients ($P = .121$). In the severe LVD group the estimated 48-month survival rate was 68% in CABG patients versus 66% in OPCAB patients ($P = .336$). Despite the fact that in both moderate and severe LVD groups, OPCAB patients had a higher mean EuroSCORE (7.2 versus 5.3 in the moderate LVD group, $P < .001$; 9.6 versus 8.0 in the severe LVD group, $P < .001$) and more comorbidity, there was no difference in midterm survival rate as estimated by Kaplan-Meier method. This finding indicated very good performance of OPCAB surgery in patients with LVD. Ascione et al [2003] found a 3-year survival rate of 73%

Table 6. Adjusted Hazard Ratios for Midterm Mortality after Surgical Revascularization*

Group	Adjusted Hazard Ratio†	95% Confidence Interval	P
CABG, LVEF 30%-50%	1.00	Reference	—
OPCAB, LVEF 30%-50%	0.69	0.28-1.70	.418
CABG, LVEF <30%	1.87	1.14-3.05	.012
OPCAB, LVEF <30%	1.21	0.63-2.30	.565

*Coronary artery bypass grafting (CABG) patients with left ventricular ejection fraction 30% to 50% were considered the reference group. LVEF indicates left ventricular ejection fraction; OPCAB, off-pump coronary artery bypass.

†Adjusted for preoperative and intraoperative variables.

in OPCAB patients versus 87% in CABG patients, but this difference was not statistically significant. However, Ascione et al included patients who were operated on before 1998 without the advantage of innovative techniques.

The preoperative EuroSCORE surgical risks of 7.2 and 9.6 in the OPCAB groups were accompanied by overall 30-day mortalities of 3.3% and 6.8% in the moderate and severe LVD groups, respectively. Our 30-day mortality rate in OPCAB patients with severe LVD was well in accordance with findings in other studies, which have shown 30-day mortality rates between 4% and 7% [Arom 2000, Tugtekin 2000, Meharwal 2002, Al Ruzzeah 2003, Ascione 2003]. Moreover, there were no significant differences in major postoperative complications between OPCAB and CABG patients in both the moderate and the severe LVD groups. This observation further supported the comparable midterm survival results between OPCAB and CABG patients, because major postoperative complications have been proved to have a detrimental effect on long-term outcome after coronary revascularization [Toumpoulis 2004a, 2004b].

It was interesting that in our study OPCAB patients had percentages of 3-vessel disease similar to those of CABG patients in both the moderate and the severe LVD groups. However, OPCAB patients received fewer multiple arterial grafts and fewer distal anastomoses in both LVD groups. This finding was observed in other studies [Arom 2000, Tugtekin 2000, Meharwal 2002, Shennib 2002, Racz 2004, Sabik 2004]. To create adjusted comparisons between the OPCAB and CABG groups we performed multivariable Cox regression analyses while adjusting for only preoperative characteristics or preoperative and intraoperative characteristics. In the first case, when CABG patients with an LVEF of 30% to 50% were considered the reference group, OPCAB patients with an LVEF of 30% to 50% had a hazard ratio of 1.32, but this value was not statistically significant ($P = .481$). CABG patients and OPCAB patients with LVEF <30% had the same hazard ratio of 1.86. This finding means that these groups had 86% increased risk for midterm mortality compared with the reference group and that this difference was statistically significant ($P = .011$ and $P = .039$) (Table 5). In the second multivariable Cox regression analysis, the groups were compared while adjustment was made for preoperative and intraoperative factors, including arterial grafts and number of distal anastomoses. In this case we noticed the same difference between the reference group (CABG with LVEF 30%-50%) and the CABG group with LVEF <30% as in a previous Cox regression analysis. The OPCAB group with LVEF <30%, however, had a hazard ratio of 1.21, which was not statistically significant compared with the value for the reference group ($P = .565$) (Table 6). In other words, when the groups were adjusted additionally for number of distal anastomoses and multiple arterial grafts, the OPCAB patients with LVEF <30% had no difference in midterm survival compared with CABG patients with an LVEF of 30% to 50%. This finding is very important. Because there is evidence that OPCAB can be successfully used for total arterial revascularization [Muneretto 2003], use of this procedure in patients with LVD may further improve both midterm and long-term outcome.

The present study had several limitations. First, it was a nonrandomized, retrospective study. Nevertheless, the information was collected with highly standardized methods for the New York State audited database. Second, the OPCAB or CABG surgical procedure used in each case was largely influenced by the surgeon's preference. Third, we examined all-cause midterm mortality. Because cause of death was not documented and it was not necessarily related to cardiac disease, survival in relation to graft patency was unknown. However, administrative follow-up can be very useful, particularly when the outcomes to be examined are limited to all-cause mortality, which is less prone to error than administrative coding of medical diagnoses or procedures. There are, however, limitations of this approach, including inability to match patients and to confirm a patient's status as alive. Fourth, we had no follow-up data on reintervention after the operation, which is a valuable parameter and affects midterm outcome.

In conclusion, patients with LVD can derive midterm benefit from coronary bypass, whereas OPCAB in higher-risk patients demonstrated early and midterm results similar to those of CABG. Complete arterial OPCAB revascularization may further improve the results, but this hypothesis remains to be confirmed with a prospective, randomized trial involving patients with LVD restricted only to surgeons who are adequately experienced in both CABG and OPCAB techniques.

REFERENCES

- Al Ruzzeah S, Athanasiou T, George S, et al. 2003. Is the use of cardiopulmonary bypass for multivessel coronary artery bypass surgery an independent predictor of operative mortality in patients with ischemic left ventricular dysfunction? *Ann Thorac Surg* 76:444-51.
- Arom KV, Flavin TF, Emery RW, et al. 2000. Is low ejection fraction safe for off-pump coronary bypass operation? *Ann Thorac Surg* 70:1021-5.
- Ascione R, Narayan P, Rogers CA, et al. 2003. Early and midterm clinical outcome in patients with severe left ventricular dysfunction undergoing coronary artery surgery. *Ann Thorac Surg* 76:793-9.
- Bouchart F, Tabley A, Litzler PY, et al. 2001. Myocardial revascularization in patients with severe ischemic left ventricular dysfunction: long term follow-up in 141 patients. *Eur J Cardiothorac Surg* 20:1157-62.
- Carr JA, Haithcock BE, Paone G, et al. 2002. Long-term outcome after coronary artery bypass grafting in patients with severe left ventricular dysfunction. *Ann Thorac Surg* 74:1531-6.
- Cox DR. 1972. Regression models and life-tables. *J R Stat Soc* 34:187-220.
- DeRose JJ, Toumpoulis IK, Balam SK, et al. 2004. Preoperative prediction of long-term survival following coronary artery bypass grafting in patients with low left ventricular ejection fraction ($\leq 25\%$). *J Thorac Cardiovasc Surg*. In press.
- Jasinski MJ, Wos S, Olszowka P, et al. 2003. Dysfunction of left ventricle as an indication for off-pump coronary artery bypass grafting. *Heart Surg Forum* 6:E85-8.
- Kaplan EL, Meier P. 1958. Nonparametric estimation from incomplete observations. *J Am Stat Assoc* 53:547-81.
- Meharwal ZS, Trehan N. 2002. Off-pump coronary artery bypass grafting in patients with left ventricular dysfunction. *Heart Surg Forum* 5:41-5.

Milano CA, White WD, Smith LR, et al. 1993. Coronary artery bypass in patients with severely depressed ventricular function. *Ann Thorac Surg* 56:487-93.

Moshkovitz Y, Sternik L, Paz Y, et al. 1997. Primary coronary artery bypass grafting without cardiopulmonary bypass in impaired left ventricular function. *Ann Thorac Surg* 63:S44-7.

Muneretto C, Bisleri G, Negri A, et al. 2003. Off-pump coronary artery bypass surgery technique for total arterial myocardial revascularization: a prospective randomized study. *Ann Thorac Surg* 76:778-82.

O'Connor CM, Velazquez EJ, Gardner LH, et al. 2002. Comparison of coronary artery bypass grafting versus medical therapy on long-term outcome in patients with ischemic cardiomyopathy (a 25-year experience from the Duke Cardiovascular Disease Databank). *Am J Cardiol* 90:101-7.

Racz MJ, Hannan EL, Isom OW, et al. 2004. A comparison of short- and long-term outcomes after off-pump and on-pump coronary artery bypass graft surgery with sternotomy. *J Am Coll Cardiol* 43:557-64.

Sabik JF, Blackstone EH, Lytle BW, et al. 2004. Equivalent midterm outcomes after off-pump and on-pump coronary surgery. *J Thorac Cardiovasc Surg* 127:142-8.

Shennib H, Endo M, Benhamed O, et al. 2002. Surgical revascularization in patients with poor left ventricular function: on- or off-pump? *Ann Thorac Surg* 74:S1344-7.

Toumpoulis IK, Anagnostopoulos CE, DeRose JJ, et al. 2004. European system for cardiac operative risk evaluation predicts long-term survival in patients with coronary artery bypass grafting. *Eur J Cardiothorac Surg* 25:51-8.

Toumpoulis IK, Anagnostopoulos CE, DeRose JJ, et al. 2004. The impact of deep sternal wound infection on long-term survival after coronary artery bypass grafting. *J Am Coll Cardiol* 43(suppl 1):298.

Toumpoulis IK, Anagnostopoulos CE, Katritsis DG, et al. 2004. Influence of innovative techniques on midterm results in patients with minimally invasive direct coronary artery bypass and off-pump coronary artery bypass. *Heart Surg Forum* 7:31-6.

Tugtekin SM, Guliemos V, Cichon R, et al. 2000. Off-pump surgery for anterior vessels in patients with severe dysfunction of the left ventricle. *Ann Thorac Surg* 70:1034-6.

Williams BC, Demitrack LB, Fries BE. 1992. The accuracy of the National Death Index when personal identifiers other than Social Security number are used. *Am J Public Health* 82:1145-7.

REVIEW AND COMMENTARY

Commentary by Editorial Board Member MB 134

What is the meaning of the data set in Tables 2 and 4 that refers to “Microscope use, n (%)”? Does this refer to the operating microscope or to surgical loupes?

Author's Response by Dr. Toumpoulis

“Microscope use” refers to use of the Leitz or Zeiss operating microscope (magnification 10× to 12×) mainly by one of the attending surgeons (D.G.S.). The rest of the operations were performed with the aid of surgical loupes. Surgical microscope use was not an independent predictor of long-term mortality in this series.

Commentary by Editorial Board Member MB 134

What are the implications of the Figure where the off-pump coronary bypass (OPCAB) patients appeared to have worse survival in each year up to the fourth year, when the survivals equalized? Does this imply that OPCAB results are really inferior to those of conventional coronary artery bypass grafting (CABG) in patients with left ventricular (LV) dysfunction (at least until many have died and the all-cause mortality equalizes)?

Author's Response by Dr. Toumpoulis

The Figure does not show matched groups of patients but rather the entirety of both groups (CABG versus OPCAB). The significantly higher European System for Cardiac Operative Risk Evaluation value (EuroSCORE) of the OPCAB groups (Tables 2 and 4) probably accounts for the early inferior survival in the OPCAB groups. We showed in a previous study that EuroSCORE is an independent predictor of long-term mortality after CABG (Toumpoulis 2004a). However, when adjustment was made according to results of Cox regression analysis (Table 5, adjustment for preoperative characteristics; Table 6, adjustment for preoperative and intraoperative variables), there was no difference in long-term mortality between CABG and OPCAB patients. It was interesting that when the groups were adjusted for intraoperative variables (number of distal anastomoses and multiple arterial grafts), the OPCAB patients with LV ejection fraction <30% had no difference in midterm survival compared with CABG patients with an LV ejection fraction of 30% to 50%.