

Late Outcome of Reoperative Coronary Revascularization on the Beating Heart

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ABSTRACT

Background: Reoperative (redo) coronary artery bypass grafting (CABG) is associated with a higher morbidity and mortality than first-time CABG. An off-cardiopulmonary bypass (off-pump) approach to redo CABG, however, may potentially benefit redo patients. The aim of the present report is to describe the early and long-term clinical outcome of patients who underwent off-pump redo CABG between July 1985 and January 1999 in our institution.

Methods: Redo patients (n = 138) represented 13% of patients who had off-pump CABG during the period of study (n = 1072). Mean patient age was 63 ± 12 years, and 67% were men. Surgical approaches included median sternotomy (n = 93, 67%), anterior (n = 20, 15%) and lateral (n = 25, 18%) minimally invasive direct coronary artery bypass (MIDCAB).

Results: Operative mortality was 2% (n = 3). Target lesion re-intervention was 6% (n = 9). Actuarial survival at a mean period of follow-up of 2.5 ± 1 year (range: 1 month to 11 years) was 83%. Event-free survival (freedom from death, myocardial infarction, and repeat intervention) was 67%. Overall cardiac-related mortality was 10% (n = 14).

Conclusion: Off-pump redo CABG can be safely performed with a relatively low mortality rate and a low rate of target lesion revascularization.

INTRODUCTION

Reoperative (redo) coronary artery bypass grafting (CABG) accounts for approximately 8% of all myocardial revascularization procedures in the United States annually [www.sts.org/graphics/sts/db/us98/gchart28]. Conventional redo CABG has been associated with a relatively high early mortality (3.4-12.5%) when compared with first-time CABG [Kron 1989, Fanning 1993, Luciani 1993, Langenburg 1995, Boonstra 1997, Kron 1997].

Although many surgical techniques have evolved that appear to improve outcomes after redo CABG with cardiopulmonary bypass (on-pump CABG) [Savage 1994], it is CABG without cardiopulmonary bypass (off-pump CABG) that may be of particular benefit in redo CABG surgery. Compared with on-pump techniques, off-pump CABG has been associated with decreased foreign-surface/blood interactions and shear response [Allen 1997], lower stroke rates, and improved perioperative outcomes [Stamou 2000a, BhaskerRao 1998]. Off-pump CABG may also be of particular benefit in reoperated patients with atherosclerosis of the ascending aorta, who are at higher risk for atheromatous embolization during aortic cannulation [Cernaianu 1995].

The purpose of this study was to evaluate the late clinical outcomes of patients who underwent off-pump CABG, since the introduction of beating heart approaches in our institution.

METHODS

Patients

The computerized database of the Division of Cardiac Surgery of the Washington Hospital Center was used to identify all patients who underwent redo off-pump CABG since the introduction of these techniques in our institution, from January 1985 until January 1999; 138 patients were so identified. These 138 off-pump redo patients represented 13% of the total number of patients (n = 1072), who

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Table 1. Baseline clinical characteristics

	Off-pump redo CABG n = 138
Age (years)	67 ± 10
Age > 75 years	35 (25)
Male gender	108 (78)
Diabetes	92 (67)
Hypertension	78 (56)
History of cerebrovascular accident	13 (9)
Chronic renal failure	6 (4)
History of COPD	13 (9)
Ejection fraction < 34%	59 (43)
CCS class III/IV	87 (63)
Urgent / emergent CABG	85 (62)
Parsonnet score	25 ± 8

Variables are expressed as mean ± SD or n (%). COPD = chronic obstructive pulmonary disease; CCS = Canadian Cardiological Society angina class

had off-pump CABG during the period of study. Clinical events were source-documented and adjudicated. Baseline demographics, procedural data, and perioperative outcomes were recorded and entered prospectively in a prespecified database by a dedicated data coordinating center. Off-pump redo CABG was performed using one of three surgical approaches: median sternotomy and anterior or lateral minimally invasive direct coronary artery bypass (MIDCAB). A median sternotomy approach was favored in grafting of the right coronary artery or posterior descending branch. Main indications for anterior MIDCAB included isolated proximal disease of the left anterior descending or first diagonal artery, and the principal indication for lateral MIDCAB was bypass regrafting of the circumflex system. Surgical techniques and selection criteria for off-pump CABG have been described elsewhere [Stamou 2000a, Stamou 2000c].

Definitions

Previous cerebrovascular accident was defined as history of a central neurologic deficit persisting for more than 24 hours. Chronic renal insufficiency was defined as a serum creatinine value ≥ 2.0 mg/dL. Diabetes was defined as a history of diabetes mellitus, regardless of duration of disease or need for oral agents or insulin. Prolonged ventilation was defined as the need for respiratory support for > 24 hours. Perioperative myocardial infarction was diagnosed by the following criteria: prolonged (> 20 min.) typical angina, creatine phosphokinase (CK)-MB fraction enzyme elevation > 40 mg/dL, and serial ECG (at least two) showing new ischemic changes. Low cardiac output syndrome was defined as the need for postoperative inotropic support for > 24 hours. Postoperative stroke was defined as any new neurologic deficit presenting in-hospital and persisting > 72 hours. Target vessel was defined as either the graft used as a conduit or the native coronary vessel that was bypassed. Major adverse cardiac events included death, Q-wave myocardial infarction, target vessel percutaneous transcatheter intervention, or redo CABG.

Table 2. Operative and postoperative characteristics

	Off-pump redo CABG n = 138
Number of grafts	1 ± 0.4
Grafted vessel	
Left anterior descending artery	84 (61)
Circumflex system	43 (31)
Right coronary artery	18 (13)
Surgical approach	
Median sternotomy	93 (67)
Anterior MIDCAB	20 (15)
Lateral MIDCAB	25 (18)
Packed red blood cells (units)	1 ± 0.2
Intra-operative transfusions	19 (14)
Reoperation due to bleeding	1 (1)
Postoperative transfusions	47 (34)
Stroke	2 (1)
Prolonged ventilation	4 (3)
Hemodialysis	2 (1)
New-onset atrial fibrillation	27 (20)
Acute non-inflammatory pericarditis	23 (17)
Low output syndrome	16 (12)
Postoperative intra-aortic balloon pump support	11 (8)
Q-wave myocardial infarction	2 (1)
Cardiac- or bleeding-related reoperation	3 (2)
Postoperative length of stay (days)	6 ± 2
Operative mortality	3 (2)

Variables are expressed as mean ± SD or n (%)

Anesthesia and Intraoperative Monitoring

Routine hemodynamic, electrocardiographic, and arterial blood gas monitoring were performed during the procedures. The anesthetic protocol for off-pump CABG has been described elsewhere [Resano 2000]. Postoperative pain control was achieved with intravenous doses of propofol (50 mg/kg) and morphine (2 mg), as needed.

Follow-up

After Institutional Review Board approval, follow-up information was obtained from the patients or their referring physicians. The period of follow-up ranged from 1 month to 11 years, with a mean of 2.5 ± 1 year. Events documented and adjudicated were death (cardiac plus noncardiac), hospitalized Q-wave myocardial infarction, hospitalized stroke, coronary angiogram, and need for a subsequent revascularization procedure (percutaneous transcatheter intervention or redo CABG). When the cause of death was unknown, a cardiac-related cause was presumed. Informed consent was obtained from all patients.

Statistical Analysis

Data are expressed as percentages or as means ± standard deviation. A stepwise logistic regression analysis was conducted to define predictors of postoperative stay > 5 days (discharge to home). The criterion for a variable entry

Table 3. Early and late mortality after redo off-pump CABG

Patient (case no.)	Age	Interval (days)	Cause	Parsonnet score	Postoperative Complications
Early mortality					
# 54	78	1	Myocardial failure	30.5	Prolonged ventilation, cardiac arrest, low-output syndrome
# 132	78	12	Multi-organ failure	30	Arrhythmias, low-output syndrome
# 135	78	11	Myocardial failure	35	Prolonged ventilation, arrhythmias, MI, low-output syndrome
Late mortality					
# 5	81	1170	Myocardial failure	22	
# 12	78	365	Congestive heart failure	28	
# 15	85	38	Unknown (presumed cardiac)	25	
# 16	78	127	Unknown (presumed cardiac)	27.5	
# 20	79	180	Unknown (presumed cardiac)	19.5	
# 23	73	86	Myocardial failure	29.5	
# 29	53	1230	Non-cardiac (colon cancer)	10	
# 33	74	365	Unknown (presumed cardiac)	38.5	
# 44	85	690	Unknown (presumed cardiac)	37	
# 62	79	120	Unknown (presumed cardiac)	51.5	
# 108	53	450	Unknown (presumed cardiac)	13.5	Myocardial infarction
# 127	78	35	Congestive heart failure	30.5	

into the logistic model was a univariate probability level of $p < 0.2$. P values < 0.05 were considered statistically significant. Actuarial and event-free Kaplan-Meier survival curves were created to estimate cumulative survival after redo off-pump CABG. Event-free survival was defined as freedom from hospitalized myocardial infarction, death, and target vessel re-interventions (percutaneous transcatheter interventions or redo CABG). All statistical analyses were performed using SPSS 9.0 for Windows 95 (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL).

RESULTS

None of the 138 patients needed conversion to on-pump CABG. Ventricular tachyarrhythmias were not observed in any of our patients when the distal anastomoses were performed.

Baseline clinical characteristics are summarized in Table 1 (●). Operative and postoperative variables are presented in Table 2 (●). The median number of grafts was one (mean: 1 ± 0.4). More patients received one graft (77%, $n = 106$) than two (19%, $n = 26$) or three (4%, $n = 6$), and more patients had first-time (86%, $n = 119$) than second-time (13%, $n = 17$) or third-time redo (1%, $n = 2$) operations. The average interval between the initial procedure and redo CABG was 9 ± 5 years. Arterial conduits only were used in 59% of patients (internal mammary artery, $n = 59$, radial artery, $n = 19$, gastroepiploic artery, $n = 3$); venous conduits only were used in 36%; and both venous and arterial conduits were used in 5%.

Early Clinical Outcome

No patient needed a repeat revascularization procedure in-hospital. The operative mortality rate was 2% ($n = 3$).

Expected Parsonnet-estimated mortality [Parsonnet 1989] was 8% ($p = \text{NS}$). Causes of in-hospital death included myocardial failure as a result of acute myocardial infarction ($n = 2$) and multi-organ failure ($n = 1$) (Table 3, ●).

Late Clinical Outcome

Complete postoperative follow-up was available in 94% of the patients and ranged from 1 month to 11 years, with a mean follow-up period of 2.5 ± 1 years. Eight patients were lost to follow-up. Repeat target-vessel CABG was needed in a patient who presented with unstable angina due to left main stenosis 90 days after the redo off-pump CABG procedure. Repeat target-vessel percutaneous transcatheter intervention was required in eight patients (6%) due to graft stenosis (Table 4, ●). Late Q-wave myocardial infarction and stroke occurred in two (2%) and three (2%) of patients, respectively. Actuarial survival at a mean period of follow-up of 2.5 ± 1 year (range 1 month to 11 years) was 83%, and event-free survival (freedom from death, myocardial infarction, and repeat intervention) at 2.4 ± 1 years was 67%. Overall cardiac-related mortality was 10% ($n = 14$).

DISCUSSION

Redo coronary revascularization remains a source of significant morbidity and mortality in patients suffering from coronary artery disease [Langenburg 1995]. Although the mortality associated with redo CABG operations has significantly declined in past years, morbidity remains significant [Kron 1989, Fanning 1993, Luciani 1993, Savage 1994, Langenburg 1995, Allen 1997, Boonstra 1997, Kron 1997]. Replacement of a diseased vein graft in patients with already limited cardiac reserve is believed to pose a greater

Table 4. Late events after redo off-pump CABG

	Off-pump redo CABG n = 138
Major adverse cardiac events	20 (14)
Q-wave myocardial infarction	3 (2)
Stroke	3 (2)
Target vessel re-intervention	
Redo CABG	1 (1)
Repeated transcatheter intervention	8 (6)
Overall cardiac-related mortality	14 (10)

Variables are expressed as %.

risk for the myocardium than does the bypass of diseased native coronary vessels [Cernaianu 1995].

Operative complications may be mitigated by avoiding the hemodynamic and cerebral effects of cardiopulmonary bypass [Allen 1997, BhaskerRao 1998]. Minimally invasive approaches may be of particular benefit in redo patients. In our series, MIDCAB was preferred for high-risk redo patients in an effort to avoid the hazards of repeat sternotomy [Ungerleider 1985]. Further, adhesions from previous sternotomies, in addition to the use of an epicardial stabilizer, may have a local stabilizing effect, reducing the motion of the heart and thereby facilitating arteriotomy and anastomosis [Coulson 1998, Talwalkar 1998]. Moreover, avoidance of cardiac cannulation and dissection of adhesions, as required by a sternotomy approach, may eliminate the repeated lifting and manipulation of the heart that has been related to increased risk of embolization of the native coronary arteries by dislodging atherosclerotic debris from the old but still patent grafts [Jain 1995].

The postoperative transfusion rate (34%) was low compared to transfusion rates of 50% to 77% reported after conventional on-pump CABG [Bracey 1995, Doty 1998]. Moreover, the postoperative atrial fibrillation rate in our series was relatively low (20%) compared with that associated with on-pump CABG (27-37%) [Allen 1997, Stamou 2000a]. Off-pump CABG surgery has been associated with a lower rate of atrial fibrillation [Cohn 1999, Stamou 2000a, Stamou 2000b] than on-pump CABG, most probably due to less manipulation of the atria and the absence of cardioplegic solution and cardiopulmonary bypass [Stamou 2000b].

The abbreviation of postoperative stay in redo patients was a trend that developed in the more recent years of the study. Specifically, for the first half of the study period (1987-1994), the median postoperative stay was seven days (mean, 7 ± 1 days), whereas for the second half (1994-1999), the median postoperative stay was 5 days (mean, 5 ± 2 days). In the current era of reduced health-care refunds, a shortened hospital stay may favorably affect the relative risk/benefit ratio for cardiac operations, and therefore lower the cost of care.

An interesting trend documented in our study was the increasing percentage of patients receiving one or more arterial grafts. Use of arterial grafts has been associated with a better short- and long-term outcome [Morris 1996]. Fewer patients operated on during the first half of the

Table 5. Published series of operative mortality rates in redo CABG

Series	Time frame	Patients (n)	Mortality
Off-pump redo			
Fanning et al., 1993	1979-1992	59	3%
Subramanian et al., 1996	1994-1995	18	0%
Mohr et al., 1997	1988-1994	77	5%
Allen et al., 1997	1995-1996	23	4%
Boonstra et al., 1997	1995-1996	81	0%
Doty et al., 1998	1994-1997	81	11%
Bergsland et al., 1998	1995-1996	105	1%
Miyaji et al., 1999	1995-1999	25	4%
Stamou et al.	1992-1999	91	1%
On-pump redo			
Allen et al., 1997	1995-1996	12	17%
Bergsland et al., 1998	1995-1996	184	3%
Stamou et al.	1992-1999	41	12%

study period (n = 7, 18%) received arterial grafts than did those operated on during the second half of the study period (n = 34, 34%, $p = 0.01$), reflecting a shift in cardiac surgical practice during the past decade.

The operative mortality rate was relatively low (2%) and comparable with rates reported for redo CABG patients, either with or without cardiopulmonary bypass [Fanning 1993, Jain 1995, Subramanian 1996, Allen 1997, Boonstra 1997, Mohr 1997, Bergsland, 1998, Miyaji 1999, Stamou 2000] (Table 5, ●). However, large prospective studies are required to properly investigate mortality differences between the two techniques.

In our series, overall cardiac-related mortality throughout the 14 years of the study period was low (10%). Despite encouraging early reports [Pfister 1992], off-pump surgery raised concerns regarding the technical limitations and the accuracy of the anastomosis [Ullyot 1996, Berger 1999].

In our study, the repeat intervention rate in a mean period of follow-up of 2.5 ± 1 years seems encouraging. The learning curve of off-pump approaches may account for the 6% graft failure rate recorded in our series. Interestingly, the repeat intervention rate was arithmetically higher in the first half of the study period (n = 3, 11%) than in the second half (n = 5, 5%, $p = \text{NS}$) (Mehran 2000).

LIMITATIONS

The limitations of our study include the retrospective single-institution methodology, the small number of patients, the inability to conduct a reliable multivariate analysis of predictor variables of late mortality due to the small number of patients with the index event. Moreover, in our initial experience, application of redo off-pump CABG was possible only for limited coronary artery disease of one or two vessels. However, an off-pump approach may allow treatment of the "culprit" lesion of the diseased coronary artery in high-risk patients with multivessel coronary artery disease. These issues should be investigated in

larger, prospective randomized studies and set the indications and contraindications of beating heart approaches.

CONCLUSION

Off-pump redo CABG is associated with relatively low morbidity and mortality and (potentially) reduced health-care costs. Long-term clinical outcome after off-pump CABG seems promising.

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