Beating Heart Versus Conventional Reoperative Coronary Artery Bypass Surgery

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Background: The incidence of reoperative coronary artery bypass grafting is increasing with an increase in the number of patients undergoing coronary artery bypass surgery. The clinical outcome of redo coronary artery bypass grafting without cardiopulmonary bypass and conventional coronary artery bypass grafting using cardiopulmonary bypass are different.

Methods and Results: We compared clinical parameters in patients who underwent off-pump (n=156) versus on-pump (n=194) redo coronary artery bypass grafting performed between January 1995 and December 2001 in our institute, to determine if off-pump surgery has improved the surgical outcome of redo coronary artery bypass grafting and emerged as an ideal technique. Patients who underwent on-pump redo surgery required more postoperative blood transfusion (86.53% on-pump *v.* 12.82% off-pump, p=0.001), prolonged ventilatory support (>24 hours) (16.49% on-pump *v.* 7.7% off-pump, p=0.021) and higher inotropic support (23.71% on-pump *v.* 10.89% off-pump, p=0.003). On-pump redo coronary artery bypass grafting was also associated with a prolonged stay in the intensive care unit (40±6.2 hours on-pump *v.* 20±4.1 hours off-pump, p=0.001) and longer hospital stay (9±4.2 days on-pump *v.* 5±3.4 days off-pump, p=0.001). In-hospital mortality was higher in on-pump patients than in off-pump ones (7.7% *v.* 3.2%); however, this was not statistically significant (p=0.114).

Conclusions: Off-pump redo coronary artery bypass grafting is a safe method of myocardial revascularization with lower operative morbidity and mortality, less requirement of blood products and early hospital discharge, compared with conventional on-pump redo coronary artery bypass grafting. **(Indian Heart J 2002; 54: 159–163)**

Key Words: Coronary artery bypass grafting, Coronary artery disease, Reoperation

The need for reoperation in patients with coronary artery disease is increasing. The incidence of redo coronary artery bypass grafting (CABG) is approximately 3% at 5 years, 11% at 10 years and 17% at 12 years.[1] An increase from 1.9% in 1980 to 7.0% in 1990[2] has been indicated by the Society of Thoracic Surgeons National Database. The technical obstacles in redo CABG are difficulty in re-entry, potential for cardiac and conduit injury during dissection, limited availability of conduits, management of patent grafts and myocardial protection. To reduce morbidity and mortality, various adaptations in surgical technique have evolved. These include minimal dissection, routine femoral cannulation and administration of antegrade and retrograde cardioplegia.

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The advent of minimally invasive techniques to perform CABG without cardiopulmonary bypass (OPCAB) may be particularly useful in redo CABG. This serves as an alternative method of "myocardial protection" as well as reduces the inherent risks of cardiopulmonary bypass (CPB). Patients with diffuse atherosclerosis of the ascending aorta may benefit from OPCAB as this technique reduces the risk of atheromatous embolization during aortic cannulation.[3]

We review our experience of redo CABG (with and without CPB) and compare the clinical outcome and early mortality between the two procedures.

Methods

From January 1995 to December 2001, 350 patients underwent redo CABG. One hundred and fifty-six patients

underwent redo OPCAB (Group A) while 194 patients underwent redo conventional on-pump CABG (conventional coronary artery bypass surgery [CCAB]: Group B). Group A consisted of 141 male and 15 female patients (mean age 60.18±6.11 years). Group B consisted of 175 male and 19 female patients (mean age 59.32±6.14 years) (p=0.193). Mean left ventricular ejection fraction was 42%±6.8% in group A and 43%±6.6% in group B (p=0.165). Fifty-seven patients in group A and 86 patients in group B had unstable angina for which emergency redo CABG was done (p=0.172); 70 patients (44.9%) had prior myocardial infarction (MI) and 11 patients (7.05%) were in congestive heart failure in group A. In group B, 96 patients (49.5%) had previous MI while 9 patients (4.6%) had congestive heart failure at the time of surgery (p=0.452 and p=0.463, respectively). Twenty-five patients (16.02%) in group A and 41 patients (21.1%) in group B had critical left main coronary artery disease but were stable at the time of induction (p=0.282). Patient-related data including risk factors are summarized in Table 1. All preoperative parameters in groups A and B were comparable.

Technique: All the surgeries were performed by senior surgeons having adequate experience and expertise in all techniques of redo surgery. Various approaches were used for redo CABG in both the groups. In group A, the routine mid-sternotomy approach was used in 112 patients, 37 patients underwent left anterior mini-thoracotomy, 6 patients left posterolateral thoracotomy and the combined approach was used in 1 patient. All 194 patients in group B underwent redo CABG via a mid-sternotomy approach. All patients were monitored hemodynamically with radial arterial, central venous and pulmonary arterial catheters, as well as by transesophageal echocardiography.

Table 1. Baseline clinical characteristics

Variable	Group A OPCAB (*n*=156)	Group B CCAB (*n*=194)
Male/female	141/15 (90.4)	175/19 (90.2)
Mean age (years)	60.18±6.11	59.32 ± 6.14
Unstable angina	57 (36.53)	86 (44.32)
CHF	11 (7.05)	9 (4.6)
PVD	9 (5.76)	6 (3.09)
Aortic atheroma	13 (8.33)	14 (7.21)
SVD	2 (1.3)	0 (0.0)
DVD	26 (16.7)	33 (17.0)
TVD	128 (82.05)	161 (83.0)
Ejection fraction (%)	42±6.8	43±6.6
Emergency CABG	57 (36.53)	86 (44.32)
IABP	12 (7.71)	17 (8.8)
Previous myocardial infarction	70 (44.9)	96 (49.5)
Diabetes mellitus	50 (32.0)	61 (31.4)
Hypertension	78 (50)	104 (53.60)
History of CVA	5 (3.2)	4 (2.06)
Left main disease	25 (16.02)	41 (21.1%)

Values in parentheses are percentages
CHF: congestive heart failure; PVD: peripheral vascular disease; SVD: single-vessel disease; DVD: double-vessel disease; TVD: triple-vessel disease; CABG: coronary artery bypass grafting; IABP: intra-aortic balloon pump; CVA: cerebrovascular accident; OPCAB: off-pump coronary artery bypass surgery; CCAB: conventional coronary artery bypass surgery

One hundred and ninety-four patients (group B) underwent redo CCAB. Median sternotomy was carefully performed with an oscillating saw. After dissecting the heart away from the sternum, the aorta and right atrium were exposed, starting at the diaphragmatic surface of the heart to enable early cannulation in case of any cardiac decompensation. Native graft manipulation was strictly avoided. Both antegrade and, wherever possible, retrograde hypothermic blood cardioplegia was given. Moderate systemic hypothermia was used during CPB.

All proximal anastomoses were done on cross-clamp with retrograde reperfusion of warm blood. One hundred and twelve patients underwent redo OPCAB via the mid-sternotomy approach. Sternal entry and adhesionolysis were similar to those for redo CCAB. Systemic heparinization with 2 mg/kg body weight of heparin was done in all off-pump cases. In patients who required a graft to the left anterior descending artery (LAD) alone, the left internal mammary artery (LIMA), if not used during the primary surgery, was grafted by the minimally invasive direct coronary bypass (MIDCAB) technique via an incision in the fourth or fifth intercostal space. The techniques for these approaches have been described in detail earlier.[4–6] In 3 patients the LAD was not graftable, hence the LIMA was used to bypass the intermedius branch via a median sternotomy on beating heart. In another patient, the LIMA was grafted on beating heart on a previously placed saphenous vein graft (SVG) to an LAD that was blocked proximally but patent distally; the distal LAD was small and intramyocardial.

Four patients in group A with blocked reversed SVGs to the circumflex territory underwent hybrid percutaneous transluminal coronary angioplasty (PTCA) to the obtuse marginal (OM) branches 5 days after redo CABG to achieve complete myocardial revascularization. In another 4 patients from group A, transmyocardial laser revascularization (TMLR) was used in the territories of the circumflex and posterior descending arteries (PDA) to revascularize the ischemic myocardium, as there was no suitable graftable vessel for CABG or PTCA (Table 2). All the 6 patients from group A who underwent posterolateral thoracotomy had patent LIMA and LAD grafts but the SVGs to OMs were blocked.

We reviewed intraoperative LIMA graft patency by Doppler flow measurement in all patients who underwent the MIDCAB procedure. Postoperative course in the intensive care unit and during hospital stay was compared in both groups.

Table 2. Conduits and number of grafts used in redo CABG

Variable	Group A OPCAB (*n*=156)	Group B CCAB (*n*=194)
Average no. of grafts/patient	1.67±0.76	2.50 ± 0.66
LIMA	124 (79.48)	147 (75.8)
RA	113 (72.43)	139 (71.64)
RSVG	137 (87.82)	173 (89.17)
RGEA	2 (1.3)	1 (0.5)
TMLR	4 (2.6)	–
Hybrid PTCA	4 (2.6)	–
CABG × 1 graft	86 (55.1)	16 (8.2)
CABG × 2 grafts	40 (25.6)	74 (38.14)
CABG × 3 grafts	26 (16.67)	95 (49.0)
CABG × 4 grafts	4 (2.6)	9 (4.6)

Values in parentheses are percentages
Types and number of grafts in each group
LIMA: left internal mammary artery; RA: radial artery; RSVG: reverse saphenous vein graft; RGEA: right gastroepiploic artery; TMLR: transmyocardial laser revascularization; PTCA: percutaneous transluminal coronary angioplasty; CABG: coronary artery bypass grafitng; OPCAB: off-pump redo coronary artery bypass surgery; CCAB: conventional redo coronary artery bypass surgery

Statistical analysis: Data are reported as mean ± standard deviation. The Chi-square or Fisher exact tests were used to compare categorical variables. Unpaired Student's *t* test was used for continuous variables between the groups. A p value of <0.05 was accepted as significant. Variables that were not normally distributed were compared using the Mann–Whitney test.

Results

Over the years, we noted an increase in the number of redo patients operated off-pump (Table 3). There were 5 hospital deaths (3.2%) in group A and 15 deaths (7.7%) in group B (p=0.114). Three patients in group A died after the MIDCAB procedure. They were in congestive heart failure and were put on an intra-aortic balloon pump (IABP) preoperatively. Of these, 1 patient underwent surgery after failed PTCA to a diseased LAD–vein graft. Two patients had acute MI with post-MI angina; they were put on IABP and taken up for surgery. Both these patients had low cardiac output and intractable ventricular arrhythmias postoperatively and died on the first and second postoperative day, respectively.

Of the 15 hospital deaths in group B, 8 patients were taken up for emergency redo CABG due to unstable angina refractory to medical management. All of them had a low ejection fraction (EF 35%–45%) and were on IABP at the time of induction. Postoperatively, they all had intractable ventricular arrhythmias with severe ventricular

Table 3. Changing trends of redo CABG

Variable	Group A OPCAB	Group B CCAB
Up to 1995	1 (0.6)	52 (26.80)
1996–1998	36 (23.07)	66 (34.02)
1999–2000	49 (31.41)	56 (28.86)
2001 onwards	70 (44.87)	20 (10.30)
Total	156	194

Values in parentheses are percentages
CABG: coronary artery bypass grafting; OPCAB: off-pump redo coronary artery bypass surgery; CCAB: conventional redo coronary artery bypass surgery

dysfunction. Three patients with an EF <35% and high pulmonary artery (PA) pressures could not be weaned away from CPB. Four patients with preoperative ventricular dysfunction had persistent postoperative low cardiac output requiring high inotropic support. They were on IABP support and could not be weaned away from the ventilator. They died within a week of redo CABG due to low cardiac output and multi-organ failure. Conversion of technique from OPCAB to CCAB was done in 7 patients. The reason in all these cases was dense pericardial adhesions with patent LIMA to LAD grafts for which it was decided to continue adequate lateral wall adhesionolysis for grafting the ramus intermedius (2 patients) and OMs (3 patients) on CPB. In 2 patients with an EF of 30%–35%, conversion from OPCAB to CCAB was done due to unstable hemodynamics while proceeding with right coronary artery anastomosis. Ventricular tachyarrhythmias were observed in 14 patients while doing distal anastomosis in the off-pump group. These were managed successfully with a bolus of intravenous lignocaine.

As shown in Table 1, there were 57 (36.53%) emergency redo CABGs in group A *v.* 86 (44.32%) in group B (p=0.172). These were the patients who developed unstable angina refractory to medical management. Twelve patients (7.71%) in group A and 17 patients (8.8%) in group B required preoperative IABP support (p=0.868). In 3 patients in group A and 2 patients in group B, IABP was inserted immediately after anesthetic induction, for high PA pressure and low EF (EF $\leq$30%). The postoperative characteristics of the patients are summarized in Table 4. Seven patients (4.48%) from group A and 14 patients (7.21%) from group B had perioperative MI based on raised

Table 4. Postoperative characteristics

	Group A OPCAB (*n*=156)	Group B CCAB (*n*=194)	p value
Mortality	5 (3.2)	15 (7.7)	0.114 (ns)
Ventricular arrhythmia	4	11	
Severe LV dysfunction + multisystem organ failure	1	4	
Cerebrovascular accident	0	2 (1.3)	0.504 (ns)
Perioperative MI	7 (4.48)	14 (7.21)	0.399 (ns)
Reoperation for bleeding	3 (1.9)	7 (3.60)	0.522 (ns)
Patient requiring Tx	20 (12.82)	168 (86.59)	0.001
Atrial fibrillation	5 (3.20)	14 (7.21)	0.159 (ns)
Prolonged ventilator (>24 hours)	12 (7.7)	32 (16.49)	0.021
Postop inotropic support	17 (10.89)	46 (23.71)	0.003
ICU stay (hours)	20±4.1	40±6.2	0.001
Hospital stay (days)	5±3.4	9±4.2	0.001

All variables are expressed as numbers and percentages. Values in parentheses are percentages

LV: left ventricular; MI: myocardial infarction; Tx: tranfusion; ICU: intensive care unit; ns: not statistically significant; OPCAB: off-pump redo coronary artery bypass surgery; CCAB: conventional redo coronary artery bypass surgery

creatine phosphokinase (CPK-MB) levels or ECG changes (p=0.399). Three patients (1.9%) from group A and 7 patients (3.6%) from group B required reoperation for hemorrhage (p=0.522). Twenty patients (12.82%) from group A and 168 patients (86.59%) from group B required postoperative blood transfusion. This was statistically significant (p=0.001). The average blood requirement was 1.2 units/patient in group A versus 2.6 units/patient in group B. Five patients (3.20%) in group A and 14 patients (7.21%) in group B developed postoperative atrial fibrillation which was well controlled by beta-blockers (p=0.159). No patient required cardioversion for a fast rate. Stay in the intensive care unit was 20±4.1 hours in group A and 40±6.2 hours in group B (p=0.001). Hospital stay was 5±3.4 days in group A and 9±4.2 days in group B (p=0.001). All patients who underwent the MIDCAB procedure had adequate diastolic LIMA flow on intraoperative Doppler flow studies of the grafted vessel.

Coronary angiography was done on the fifth postoperative day in 25 patients in group A and 15 patients in group B. In all these cases, patency of the redo grafts was confirmed. Four of these patients from group A underwent a simultaneous hybrid PTCA with check angiography for occluded primary OM vein grafts. Four patients had MIDCAB and TMLR to the posterolateral and inferior walls and tolerated the procedure well.

Discussion

As the surgical trend is universally towards minimally invasive techniques, we too observed an increase in the number of off-pump redo CABG surgeries during the course of our study (Table 4). Off-pump redo CABG aims at providing a safe surgical technique, depending on the need of an individual patient so as to reduce the high mortality and morbidity associated with all redo CABGs.[7–9]

Even in the presence of improved perfusion techniques, the potential hemodynamic and cerebral hazards of CPB remain, more so in cases of redo CABG where one expects prolonged pump time.[10,11] In this study, we found that OPCAB had lower rates of morbidity and mortality as compared to CCAB. Although the mortality rates are not statistically significant, low mortality in the large number of patients who underwent redo CABG is encouraging. Specifically, off-pump redo CABG was associated with less need for intraoperative and postoperative blood transfusion, as also documented by others.[10,12,13] Patients undergoing on-pump redo CABG had an almost 3-fold increased incidence of prolonged ventilatory support and a significant increase in postoperative inotropic support. There is a higher incidence of atrial fibrillation in CCAB patients,[10,12,14,15] as seen in our study as well. This can be attributed to systemic hypothermia, atrial manipulation and greater surgical trauma as compared to off-pump cases. Increased cardiac trauma and myocardial injury as seen with raised troponin-T and CPK levels can be associated with a defective adaptive response of the heart muscle to this surgical stress and prolonged aortic cross-clamping.[16,17] Reports of reduced cytokinase response and myocardial injury have also been noted with off-pump redo CABG.[18] Off-pump redo CABG has significantly shortened hospital stay, thus reducing hospital resourses and health care costs. Studies have shown the use of CPB as an independent predictor of prolonged hospital stay.[12,19,20]

Hemodynamic intolerance to coronary manipulation during grafting of the posterior descending artery or the RCA usually mandates a conversion to on-pump surgery and obviates consideration of the off-pump technique. We had only 2 patients who had to be converted to on-pump due to hemodynamic instability while grafting the RCA.

For redo patients, the MIDCAB procedure avoids manipulation of patent grafts and mobilization of adhesions from the previous operation. In all our patients who underwent MIDCAB, the LIMA flow measured by Doppler revealed adequate diastolic flow, this being a reflection of patent distal anastomosis. Others have also advocated MIDCAB as an acceptable procedure.[21,22]

Off-pump OM revascularization using a thoracotomy approach, as described by Baumgartner and colleagues,[23] was successfully performed in 6 patients in our series to bypass the OM branches, using SVGs in 4 patients and radial artery grafts in 2 patients. Proximal anastomosis was carried out on the descending aorta as all these patients had patent LAD grafts, thus proving the success of this

approach for selected patients. The mortality in our study is comparable with that reported in various other series.[12,24,25]

In summary, the introduction of off-pump CABG in clinical practice extends the various benefits of coronary revascularization to a group of patients otherwise considered at high risk for redo surgery. Although the technical quality of anastomosis governing the early outcome of the procedure has been excellent, the feasibility and durability of this approach will be dictated by long-term patency data. With the advent of more sophisticated but simplified myocardial stabilizers and with increasing surgical expertise, the proportion of patients undergoing off-pump CABG with its favorable results is likely to increase further, thus determining the ultimate outcome of redo CABG surgery.

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