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Off-Pump Coronary Artery Bypass Grafting in Patients with Left Ventricular Dysfunction

Dr. Meharwal

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Zile Singh Meharwal MCh, Naresh Trehan, MD

Department of Cardiovascular Surgery, Escorts Heart Institute And Research Centre, New Delhi, India

ABSTRACT

Background: Coronary artery bypass grafting in patients with severe left ventricular (LV) dysfunction still remains a high risk procedure due to its high mortality and morbidity. Off-pump surgery can be an alternative technique in these patients. We analyzed our results of off-pump coronary surgery in patients with left ventricular dysfunction and compared them with patients operated on-pump.

Methods: Between January 1997 and December 2000, 355 patients with LV dysfunction (EF equal to or less than 30%) underwent off-pump coronary artery bypass (OPCAB) surgery. During the same period, 959 patients with LV dysfunction underwent coronary artery surgery on cardiopulmonary bypass. Octopus was used as mechanical stabilizer and intracoronary shunts were used in most patients. The mean age of the patients was 57.7 ± 9.2 in patients operated on-pump and 58.4 ± 9.8 in patients operated off-pump.

Results: The preoperative variables were comparable in two groups, except that there were more patients with triple vessel disease in on-pump group. Average number of grafts was 2.8 ± 0.7 and 3.3 ± 0.7 ($p<0.001$) in off-pump and on-pump groups respectively. The mortality was 3.9% and 6.0% ($p = 0.176$) in off-pump and on-pump groups respectively. Postoperative morbidity was less in off-pump group but it was statistically significant in incidence of atrial fibrillation and prolonged ventilation which were low in off-pump group. The hospital stay was significantly less in patients operated off-pump.

Conclusion: OPCAB surgery can be safely performed in patients with LV dysfunction. The postoperative morbidity and length of stay is less as compared to patients operated on-pump.

INTRODUCTION

Despite many advances in techniques of coronary artery bypass grafting (CABG), patients with severe left ventricular (LV) dysfunction still have high morbidity and mortality [Christakis 1992, Milano 1993]. The poor outcome in these patients might be partly related to adverse effects of cardiopulmonary bypass and cardioplegia. The myocardial edema intrinsic to the diastolic state of the arrested heart can cause cardiac dysfunction [Mehlhorn 1996]. The detrimental effects of aortic cross clamp might be more significant in patients with poor left ventricular function, where even small damage to myocardium can have significant clinical consequences. Off-pump technique has been used in this group of high-risk patients with encouraging results [Arom 2000, Tugtekin 2000].

We analyzed our results of coronary artery bypass grafting in patients with severe left ventricular dysfunction on cardiopulmonary bypass and without cardiopulmonary bypass.

MATERIAL AND METHODS

Between January 1997 and December 2000, 9,800 patients underwent coronary artery bypass grafting at our institute. Of these patients, 1,314 had left ventricular ejection fraction (LVEF) equal to or less than 30%. Among these patients, 959 were operated on cardiopulmonary bypass (CPB group – group A) and 355 were operated without cardiopulmonary bypass (OPCAB group – group B). The preoperative and intraoperative variables of two groups were analyzed and compared. The postoperative outcome was analyzed.

Technique of Off-pump CABG

All procedures were performed through median sternotomy. The left internal mammary artery (LIMA) was harvested by standard technique using hemoclips. It was harvested as pedicled graft in most patients. The radial and vein were harvested simultaneously. Patient was heparinized with a dose of 1.5mg/kg body weight. Octopus 2, Octopus 2+ and Octopus 3 (Medtronic, Inc., Minneapolis, MN, USA) were used as the mechanical stabilizers in most of the patients. Intracoronary shunts (Baxter AnastaFLO Intravascular shunt, Irvine, CA) were used in most of the patients. The oxygen blower was used to assist in anastomosis. Hemodynamic monitoring was performed by swan ganz catheter. Continuous monitoring of arterial pressure, central venous pressure, mean pulmonary artery pressure, pulmonary capillary wedge pressure, cardiac index, stroke volume and systemic vascular resistance were done. Transesophageal echocardiography (TEE) was performed on all the patients to look for global and regional left ventricular functions before, during and after surgery.

Left anterior descending (LAD) artery was grafted as the first coronary artery in almost all cases. The right coronary

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Address correspondence and reprint requests to: Dr. Zile Singh Meharwal, Senior Consultant Cardiac Surgeon, Escorts Heart Institute And Research Centre, Okhla Road, New Delhi 110 025, India, Phone.: + 91-11-6825000, 6825001, Fax.: + 91-11-6825013, Email: meharwal@hotmail.com

Table 1. Patient's Clinical Characteristics

Clinical variable	CPB (group A) (n = 959)	OPCAB (group B) (n = 355)	p value
Age in yrs (mean ± SD)	57.7 ± 9.2	58.4 ± 9.8	0.263
Males (%)	903 (94.2)	321 (90.4)	0.024
Females (%)	56 (5.8)	34 (9.6)	
Mean EF (mean ± SD)	25.6 ± 4.1	24.8 ± 4.0	0.002
EF < 20% (%)	199 (20.8)	65 (18.3)	0.366
NYHA class IV (%)	524 (54.6)	216 (60.8)	0.051
NIDDM (%)	194 (20.2)	80 (22.5)	0.402
IDDM (%)	9 (0.9)	3 (0.8)	0.866
Hypertension (%)	108 (11.3)	34 (9.6)	0.439
Smoker (%)	351 (36.6)	144 (40.5)	0.211
COPD (%)	140 (14.6)	60 (16.9)	0.344
CVA (%)	20 (2.1)	13 (3.7)	0.154
PVD (%)	73 (7.6)	31 (8.7)	0.580
CHF (%)	205 (21.4)	95 (26.8)	0.046
Obesity (%)	129 (13.5)	66 (18.6)	0.025
Unstable angina (%)	245 (25.5)	101 (28.5)	0.322
Left main stenosis (%)	69 (7.2)	48 (13.5)	< 0.001
SVD (%)	11 (1.2)	43 (12.1)	< 0.001
DVD (%)	111 (11.6)	91 (25.6)	< 0.001
TVD (%)	837 (87.3)	221 (62.2)	< 0.001

EF, ejection fraction; NYHA, New York heart association; NIDDM, non insulin dependent diabetes mellitus; IDDM, insulin dependent diabetes mellitus; COPD, chronic obstructive pulmonary disease; CVA, cerebro vascular accident; PVD, peripheral vascular disease; CHF, congestive heart failure

artery (RCA) was normally the second artery to be grafted. The vessels on the lateral wall and posterior wall were grafted as the last vessels. However, the sequence of grafting was individualized for a particular patient, depending on patient's hemodynamics. LAD and RCA could be grafted without much displacement of heart. For exposure of the circumflex vessels, three pericardial traction sutures were used to pull the heart vertically. Right pleura was opened in majority of the patients and vertical pericardiotomy was performed to herniate the heart to right chest under the sternum. Other maneuvers, such as Trendlenberg position and tilting the table, were performed as required. Inotropes were used as and when necessary during surgery.

Proximal anastomosis was performed using standard techniques. Normally, proximal anastomosis was performed after every distal anastomosis.

Techniques of CABG on CPB

Standard cardiopulmonary bypass (CPB) was established using ascending aortic and two stage venous cannulation. The patient was not actively cooled but the temperature was allowed to drift. Most patients were operated under cardioplegic arrest, using warm blood cardioplegia, both antegrade and retrograde. Cardioplegia was repeated after every distal anastomosis. Warm blood without potassium was infused after completing all distal anastomosis, while performing proximal anastomosis. Some patients were operated on CPB without arresting the heart. The left ventricular vent was inserted through right superior pulmonary vein in some patients. The hemodynamic monitoring was performed using swan ganz catheter and TEE as in patients operated without cardiopulmonary bypass. The intra-aortic balloon pump was inserted in patients with high pulmonary artery pressures.

Statistical Analysis

Data are reported as mean ± SD. Postoperative survival was expressed by actuarial analysis. The X^2 test and Fisher Exact test were used to compare categorical variables. Unpaired Student's t-test was used to compare inter group means. A p-value of less than 0.05 was accepted as significant. Variables that are not normally distributed were compared using the Mann-Whitney test.

RESULTS

Preoperative characteristics of two groups of patients are shown in Table 1 ◉. There were more males in CPB group than in OPCAB group. The incidence of diabetes, hypertension, smokers, chronic obstructive pulmonary disease (COPD), cerebrovascular accident (CVA), peripheral vascular disease and unstable angina was comparable in two groups. The mean ejection fraction was low in OPCAB group. There were more patients with congestive heart failure in OPCAB group. The incidence of left main stenosis was significantly higher in OPCAB group. There were more patients with triple vessel disease in CPB group as compared to OPCAB group.

Majority of the patients received left internal mammary artery as the conduit for left anterior descending artery (Table 2, ◉). The other grafts used were radial artery and saphenous veins. Bilateral internal mammary artery was used in 5.2% patients in CPB group and 4.5% patients in OPCAB group (P<0.70). The average number of grafts per patient was higher in CPB group than in OPCAB group. This can be explained by more number of patients with triple vessel disease in CPB group than OPCAB group (87.2% vs. 62.2%, p <0.001).

Among patients who were operated on CPB, majority were operated with aortic cross clamp and warm blood cardioplegia (Table 3, ◉). Combination of antegrade and retrograde cardioplegia was used in majority of the patients. We did not have any complication related to the use of retrograde cardioplegia.

Total operating time was significantly lower in OPCAB group than CPB group (Table 2, ◉). The intubation time, blood loss and ICU stay were significantly lower in OPCAB group than CPB group. Significantly less number of patients in OPCAB group received blood transfusion as compared to CPB group. We used intra-aortic balloon pump in operating theatre before the procedure, when the pulmonary artery pressures were high. This was used more often in OPCAB group than CPB group. On the other hand, more patients required IABP postoperatively in CPB group than in OPCAB group.

The choice of inotrope was based on the hemodynamic parameters, including pulmonary artery pressure, cardiac output and systemic vascular resistance. The epinephrine was not normally the first inotrope of choice because of its chronotropic

Table 2. Intraoperative/Postoperative Variables

Variables	CPB (group A) (n = 959)	OPCAB (group B) (n = 355)	p value
Grafts/ patient (mean ± SD)	3.3 ± 0.7	2.8 ± 0.7	0.001
LIMA used (%)	882 (92.0)	330 (93.0)	0.632
Bilateral IMAs (%)	50 (5.2)	16 (4.5)	0.704
CPB time (mean ± SD)	80 ± 12	NA	
Aortic cross clamp time (mean ± SD)	34 ± 8	NA	
Skin to skin time (min) (mean ± SD)	236 ± 53	174 ± 48	0.001
Intubation time (hrs) (mean ± SD)	23 ± 4	14 ± 3	0.001
Blood loss (mean ± SD)	580 ± 73	360 ± 60	0.001
Blood transfusion (%)	422 (44)	114 (32.1)	0.001
ICU stay (hrs) (mean ± SD)	34 ± 12	22 ± 10	0.001
IABP (%)			
Preop	143 (14.9)	39 (11.0)	0.081
Intraop	106 (11.1)	62 (17.5)	0.003
Postop	37 (3.9)	4 (1.1)	0.019
Inotropes intraop (%)			
Dobutamine	161 (16.8)	30 (8.4)	<0.001
Epinephrine	140 (14.6)	44 (12.4)	0.351
Norepinephrine	93 (9.7)	51 (14.3)	0.021
Milrinone	62 (6.5)	0 (0.0)	< 0.001
Inotropes postop (%)			
Dobutamine	138 (14.4)	37 (10.4)	0.074
Epinephrine	159 (16.6)	41 (11.5)	0.034
Norepinephrine	132 (13.8)	22 (6.2)	< 0.001
Milrinone	50 (5.2)	5 (1.4)	0.004
Hospital stay (mean ± SD)	9 ± 5	6 ± 4	0.001

LIMA, left internal mammary artery; CPB, cardio pulmonary bypass; ICU, intensive care unit; IABP, intra aortic balloon pump; NA, not applicable; Preop, preoperative; intraop, intraoperative; postop, postoeprative

effect. Intraoperatively, norephinephrine was used in more patients in OPCAB group while dobutamine and milrinone were used in more patients in CPB group. More patients in CPB group required inotropes in postoperative period. Our use of inotropes has reduced recently because we have realized that proper positioning of the heart and other maneuvers can maintain good hemodynamics even in this group of patients.

The hospital mortality was lower in OPCAB group than CPB group (Table 4, ◉) but it was not statistically significant. The incidence of postoperative complications in two groups is shown in Table 4 (◉). The incidence of perioperative myocardial infarction, reopening for bleeding, reopening for hemodynamic instability, stroke, renal failure and infection was not significantly different in two groups. The incidence of atrial fibrillation was significantly less in OPCAB group as compared to CPB group. Significantly higher numbers of patients in CPB group required ventilation beyond 48 hours as compared to OPCAB group. The hospital stay was significantly less in OPCAB group than CPB group (Table 2, ◉).

Patients were followed from 2 months to 4 years (mean follow up 18 ± 12) months. Follow-up was complete in 802 (89%) of survivors in CPB group and 321 (91%) of survivors

Table 3. Intraoperative Variables of Patients Operated on CPB (CPB group)

Variables	CPB (group A) (n = 959)	Percentage
CPB with cross clamp	937	97.7
CPB without cross clamp	22	2.3
CPB time (mean ± SD)	80 ± 12	
Aortic cross clamp time (mean ± SD)	34 ± 8	
Cardioplegia	937	98.0
Antegrade	24	2.5
Antegrade + retrograde	913	95.5
LV vent through RSPV	22	6.1

CPB, cardiopulmonary bypass; LV, left ventricle; RSVP, right superior pulmonary vein

in OPCAB group. There were 105 (10.9%) late deaths in CPB group and 30 (8.5%) late deaths in OPCAB group (Table 5, ◉). The incidence of recurrence of angina, nonfatal myocardial infarction and re-operation in two groups was not statistically significant.

DISCUSSION

Patients with severe left ventricular dysfunction have been known to have superior long term survival by coronary artery bypass grafting (CABG) [Christakis 1988, Elefteriades 1993, Milano 1993, Shapira 1995]. CABG using (CPB) has been quite safe due to recent developments in myocardial protection techniques and in majority of patients its damaging effect on myocardium is minimal and reversible [Salern 1991, Buckberg 1993, Calafiore 1995], but patients with LV dysfunction have very poor reserve and even slight damage to myocardium may have significant consequences. Most of these patients have a combination of risk factors and mortality may reach 10% or higher [Faymonville 1991, Buffolo 1996, Calafiore 1996]. One of the ways to avoid damaging effects of CPB is to perform CABG on beating heart and some studies have

Table 4. Postoperative Complications

Variables	Group A (CPB) (n = 959)	Group B (OPCAB) (n = 355)	p value
Perioperative MI (%)	11 (1.1)	3 (0.8)	0.770
Reop for bleeding (%)	21 (2.2)	2 (0.6)	0.078
Reop for haemodynamic instability (%)	4 (0.4)	1 (0.3)	0.880
Stroke (%)	3(0.3)	1 (0.3)	0.636
Renal failure (%)	43 (4.5)	8 (2.2)	0.089
Atrial fibrillation (%)	152 (15.8)	35 (9.8)	0.008
Prolonged ventilation >48 hrs (%)	94 (9.8)	8 (2.2)	< 0.001
Sternal infection (%)	8 (0.8)	2 (0.6)	0.885
Operative mortality (%)	58 (6.0)	14 (3.9)	0.176

MI, myocardial infarction; Reop, reoperation

Table 5. Late Results

Variables	Group A (CPB) (n = 959)	Group B (OPCAB) (n = 355)	p value
Late death (%)	105 (10.9)	30 (8.5)	0.222
Cardiac	83	25	0.405
Non cardiac	22	5	0.432
Recurrence of angina (%)	49 (6.1)	26 (8.0)	0.160
Non fatal MI (%)	12 (1.5)	5 (1.6)	0.788
Reoperation (%)	20 (2.5)	8 (2.5)	0.978

MI, myocardial infarction

shown good results of CABG on beating heart in patients with poor LV [Sternik 1997, Arom 2000,Tugtekin 2000].

Cimochowski et al. [George 1997] reported a very low mortality of 1.8% in 111 patients with severe LV dysfunction undergoing CABG. They credited their good results to various metabolic and mechanical support during surgery.

Off-pump coronary artery bypass (OPCAB) was initially used in selected groups of patients but it is now being used in more and more difficult situations and many groups have reported good results in high risk patients, including patients with poor ventricular function [Sternik 1997, Yaron 1997, Arom 2000, Tugtekin 2000].

A good hemodynamic monitoring and attention to minor details during OPCAB is very important in this group of patients. TEE gives us good information about the wall motion of the left ventricle and the heart can be displaced in a direction so that there is minimal compression of the right ventricular outflow tract and minimal hemodynamic compromise.

One of the apprehensions in OPCAB is incomplete revascularization [Yaron 1997, Tugtekin 2000]. Though the average number of grafts in our study was less in OPCAB group, it was because of higher incidence of patients with triple vessel disease in CPB group. In our initial experience of OPCAB, we were using this technique in patients with single and double vessel disease but now we are performing off-pump CABG in all the patients, irrespective of the severity of the disease. The mean number of grafts, in patients with triple vessel disease, was comparable in both the groups.

Incidence of postoperative complications was low in OPCAB group than CPB group in our study. This has been demonstrated by other studies also [Kirklin 1991, Kirklin 1993, Arom 2000,Tugtekin 2000]. The hospital stay was significantly less in OPCAB group in our study, which reduces the cost of hospitalization.

The results of late follow-up were comparable in two groups of patients. The incidence of recurrence of angina, nonfatal MI and re-operation were not statistically significant between CPB and OPCAB groups.

One of the techniques to avoid the effects of myocardial ischemia and altered homeostasis during cross clamp can be to perform CABG on CPB on beating heart. Perrault et al. [Louis 1997] used this technique in 37 high-risk patients including patients with poor LV function and evolving myocardial infarction. They showed acceptable results in these patients. We used this technique in 22 patients.

Increased veins graft thrombosis has been reported as one of the risks in patients undergoing CABG on beating heart [Archer 1984, Sternik 1997]. This has been thought to be related to technical errors compromising the quality of anastomosis or to inadequate selection of patients. With the availability of good stabilizers and paying attention to various techniques for adequate exposure and maintaining hemodynamics, all the target vessels on the heart can be comfortably grafted on beating heart.

We use intra-aortic balloon pump quite liberally in this group of patients. The IABP treatment results in a more favorable myocardial supply and demand balance [Laze 1992], reduces afterload and augments the diastolic pressure which in turn leads to an increased cardiac output. Thus IABP helps to maintain the hemodynamics of the patient during OPCAB in patients with LV dysfunction.

In conclusion, CABG without CPB can be safely performed in patients with poor ventricular function. The mortality is comparable to patients operated using CPB. The morbidity is less in OPCAB group than CPB group and the length of stay is less. A proper attention to intraoperative monitoring and various surgical techniques including the use of IABP improves results. The midterm results are good.

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REVIEW AND COMMENTARY

1. Editorial Board Member GX21 writes:

This is a nice paper with impressive OPCAB results in poor LV patients.

Since this is an observational study, some of the advantages of OPCAB could be due to factors other than the operation.

a) How were patients selected to receive OPCAB?
b) With such a high volume, many surgeons must have been involved. How many?
c) What was the distribution of surgeons among the two surgical groups, that is, did some do 0% OPCAB and others 50?

Authors' Response by Zile Singh Meharwal MCh:

a) The decision to operate on a patient on-pump versus off-pump was made by the operating surgeon.
b) We have six consultant cardiovascular surgeons in our institute. All the surgeons were involved in operating on these patients.
c) Every surgeon is doing both off-pump and on-pump CABG at our institute. The percentage of OPCAB performed by surgeons is not grossly different though some surgeons do more OPCAB than others.

2. Editorial Board Member AR11 writes:

As with many retrospective studies, this manuscript suffers from comparisons between divergent and differing groups. More extensive revascularization was performed in the on-pump patients yet the data seem to indicate that the OPCAB patients were sicker. Were the sicker patients incompletely revascularized, and if so, is it fair to compare these two groups? I believe that the authors might have some meaningful message within the data presented in the manuscript but as written, it is too confusing to be of significant use.

Authors' Response by Zile Singh Meharwal MCh:

More patients in the OPCAB group had congestive heart failure and incidence of obese patients was more in this group. Regarding the severity of coronary artery disease, more patients in CPB group had triple vessel disease, though the incidence of left main stenosis was more in the OPCAB group. The number of grafts in the on-pump group was more than off-pump group because in the initial period, we were using OPCAB for patients with single and double vessel disease who required fewer grafts. Now we consider all patients for OPCAB irrespective of the severity of disease.

3. Editorial Board Member DB515 writes:

a) The issue of conversion must be addressed. Are converted patients treated as OPCAB or ONCAB? We have looked at this issue extensively and it is of great interest in this series.
b) How were the converted patients treated? We believe that in conversions, especially in low EF cases, the operation should be done with CPB as support without cardiac arrest and cardioplegia.
c) The incidence of strokes and other neuro-complications was not discussed as far as I could see.

Authors' Response by Zile Singh Meharwal MCh:

a) We had three conversions from OPCAB to CPB group. All three patients survived and had uneventful postoperative recovery but we did not include these patients in our study.
a) We also operated on these patients (who were converted to CPB group) on beating heart without arresting the heart.
a) The incidence of stroke in OPCAB and CAB group was same (OPCAB 1/355 = 0.3%, 3/959 = 0.3%, p = 0.636) as mentioned in results.