Beating Heart versus Conventional Coronary Bypass Surgery : Our Experience

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Abstract

Background: Off-pump Coronary Artery Bypass (OPCAB) has become the standard surgical treatment of Coronary Artery Disease in most centres in India. It is clear from the current evidence that, in certain patients, OPCAB offers advantages over conventional Coronary Artery Bypass Grafting (CABG). Experience of this procedure in the Armed Forces is highlighted.

Methods: Retrospective analysis of 200 nonrandomized consecutive patients taken up for OPCAB and 200 conventional CABG between Jan 2005 and Dec 2007 was done. The European system for cardiac operative risk evaluation (euroSCORE) was used in all patients. Perioperative morbidity and mortality was compared in the two groups.

Result: OPCAB was possible in 192 (96%) out of 200 patients taken up for this procedure. Eight patients required cardiopulmonary bypass (CPB) to complete the revascularization. Incidence of reoperation for bleeding was 2.5% in OPCAB and 6% in CABG. In the CABG group 2% patients developed severe bleeding complications, 3% required ventilation for more than 24 hour, 1% required renal replacement therapy, 1% had acute respiratory distress syndrome and 3.5% had neuro-psychiatric manifestations. Incidence of these complications in OPCAB patients was lower or NIL. Overall mortality in the OPCAB group was 1.5% and 2% in the CABG group. However only one patient out of 192 (0.5%) who underwent successful OPCAB died, while two patients out of eight who required conversion to CPB in this group died. Incidence of stroke, deep sternal infection and mortality was similar in both groups.

Conclusion: OPCAB is safe, effective and can be offered to more than 90% patients as the primary strategy for surgical myocardial revascularization. It has lower overall morbidity than conventional CABG. Its main limitations are hemodynamic instability and inability to find a deeply embedded target vessel. Both these factors affect the outcome adversely making conventional CABG a better option in these situations.

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Key Words : Off-pump coronary artery bypass; Coronary artery bypass

Introduction

Off-pump Coronary Artery Bypass (OPCAB) has become the main approach to surgical revascularization of the heart over the last decade in India. The popularity and widespread acceptance of this procedure has resulted primarily from the technological advances in the design of tissue stabilizers and other equipment which is essential to create a still and bloodless field required for these delicate and precise anastomoses. Unlike older models which worked by compressing a segment of the myocardium, modern tissue stabilizers like the Octopus and Acrobat use suction to adhere to the surface of the heart and stabilize a segment of the myocardium while the rest of the heart continues to beat normally without any external compression on it. Cardiopulmonary bypass (CPB) has been considered an important factor in the pathogenesis of complications of conventional Coronary Artery Bypass Grafting (CABG). With improvement in perfusion technology,

these complications are seen less frequently and the average cardiac surgical patient tolerates CPB very well. There still remain, however, patients with serious preoperative organ dysfunction who are high risk for CPB and it is in them that OPCAB has its true value. Considering that approximately 800,000 bypass operations are performed annually worldwide [1], the size of this 'high risk' group of patients is not small.

The aim of this study was to analyze the efficacy of OPCAB as the procedure of choice for surgical myocardial revascularization, its potential advantages over CABG and limitations.

Material and Methods

Retrospective analysis of two hundred consecutive patients who were offered OPCAB and a similar number who underwent conventional CABG at two Armed Forces Cardiothoracic surgical centres between Jan 2005 and Dec 2007 was carried out. Patients were not randomized to either group because the practice of OPCAB varied between

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different surgeons. Operative risk of all patients was assessed as per the European system for cardiac operative risk evaluation (euroSCORE). Patients with hybrid procedures (OPCAB / CABG plus balloon angioplasty) and combined CABG with valve repair / replacement were excluded from this study.

All procedures were done through a median sternotomy incision. Left internal mammary artery (LIMA) was used as a conduit in all patients unless contraindicated. Radial artery (RA) from the non dominant upper limb, if usable, was used in patients less than 70 years of age. A segment of saphenous vein was used as a third conduit when required. Composite grafting using both mammary arteries or LIMA and RA was done whenever the Aorta was severely diseased.

OPCAB procedures were done with an activated clotting time (ACT) maintained above 300 seconds. Swabs and deep pericardial retraction sutures were used to luxate the heart and expose the required vessel. Hemodynamic instability resulting from displacement of the heart during OPCAB was managed actively by the anaesthesiologist with a combination of positioning of the operation table, intravenous fluids and pharmacotherapy. After optimal exposure and stabilization with a suction based stabilizer system (Octopus 4.3 or Acrobat), the target vessel was opened. An appropriately sized intra-coronary shunt was placed to maintain perfusion of the dependent myocardium and distal anastomosis performed using 7/0 or 8/0 prolene suture (Fig. 1). Proximal anastomosis was done using a partial occluding vascular clamp on the ascending aorta, an aortotomy punch and 6/0 or 7/0 prolene. Sequential anastomosis of the same conduit to a second or a third target vessel was done whenever feasible (Fig. 2). The left anterior descending (LAD) artery was always grafted first. In patients with severe coronary disease and depressed left ventricular function, proximal anastomosis of a graft was constructed prior to distal anastomosis to achieve 'functional revascularization'.

Conventional CABG was done with the use of CPB and an ACT maintained above 500 seconds. Cardiac arrest and myocardial protection strategies employed differed with the operating surgeons' preference. Blood based cardioplegic solution, when used, was delivered either antegrade in the intact aortic root, or, antegrade as well as retrograde through a cannula placed in the coronary sinus.

Fig. 1 : LIMA to LAD anastomosis on beating heart with tissue stabilizer and intracoronary shunt.

After aortic cross clamp and arrest of the heart, all distal anastomoses were done first. The sequence followed was right coronary artery (RCA), obtuse marginal (OM) branches, diagonal (D) branches and lastly the LAD. Following this, the cross clamp on the aorta was removed and proximal anastomoses done. CPB was weaned off and discontinued after good cardiac function returned. Inotropic support and intra aortic balloon pump (IABP) assist was used during the weaning off process whenever required. Platelet transfusion in the form of one plasmapheresis unit or six units of random donor platelets were given to every patient operated on CPB who continued to show a bleeding tendency after administration of Protamine and reversal of ACT to the preoperative level. The subsequent steps of hemostasis and wound closure were similar in both groups.

Postoperative management of patients in both groups was similar. Patients were intensively monitored and were kept on mechanical ventilation till complete cardio-respiratory and neurological recovery. Standard criteria for weaning off the ventilator and extubation were used. All patients with significant drainage from mediastinal drains (>8ml/kg body weight at a single instance, or, continuing drainage of 2-4ml/kg/hr for 3 hour) were returned to the operation theatre for reoperation. Packed red cell transfusion was given to maintain haemoglobin above 10g/dl. Fresh Frozen Plasma and cryoprecipitate was given to reverse haemostatic defects whenever indicated. Fall in urine output to less than 0.5ml/kg/hr along with a normal central venous pressure was managed aggressively with diuretics. Operating time, number of grafts per patient, intra-operative requirement of isotropic drugs and IABP, postoperative blood loss and transfusion requirements, acute renal failure, myocardial dysfunction, cerebral dysfunction, pulmonary dysfunction, post operative atrial fibrillation, infection rate and mortality in the two groups was compared.

Results

The patients ranged in age from 36 year to 85 year (average 58.2 year). A total of 192 OPCAB procedures were carried out in 200 patients. Patient parameters are shown in Table 1. Overall 67 patients (33.5%) in the OPCAB group and 59 patients (29.5%) in the CABG group had a euroSCORE of more than 3

Fig. 2 : Second OM anastomosis. Heart has been displaced upwards to expose the vessel. Saphenous vein graft from Aorta has been sequentially anastomosed to diagonal & first OM branches already.

Table 1**Patient parameters**

Parameter	OPCAB (n=200)	CABG (n=200)
Age (<60yrs)	38 (19%)	53 (26.5%)
Female	31 (15.5%)	22 (11%)
Diabetic	53 (26.5%)	69 (34.5%)
Obesity	8 (4%)	13 (6.5%)
COPD	12 (6%)	9 (4.5%)
Extent of CAD		
Critical LMCA disease	27 (13.5%)	22 (11%)
SVD	10 (5%)	2 (1%)
DVD	49 (24.5%)	33 (16.5%)
TVD	141 (70.5%)	165 (82.5%)
Unstable angina	19 (9.5%)	26 (13%)
Recent MI (90 days)	21 (10.5%)	17 (8.5%)
LV function		
EF >0.5	107 (53.5%)	113 (56.5%)
EF 0.3-0.5	75 (37.5%)	66 (33%)
EF <0.3	18 (9%)	1 (10.5%)
Critical preoperative state:		
Inotropes	nil	3 (1.5%)
IABP	nil	2 (1%)
Serum creatinine > 2mg%	7 (3.5%)	3 (1.5%)
euroSCORE:		
0 – 2 (low risk)	133 (66.5%)	141 (70.5%)
3 – 5 (medium risk)	47 (23.5%)	43 (21.5%)
> = 6 (high risk)	20 (10%)	16 (8%)

(medium or high risk score).

Intra-operative comparison is shown in Table 2. Average number of grafts per patient in the OPCAB group was 2.9 and 3.0 in the CABG group. Operating time in the OPCAB group was longer. Target vessels in all territories, when found, could be grafted with the OPCAB technique. Conversion to CPB was required in four patients taken for OPCAB when the target vessel was located deeply in the myocardium and could not be found after superficial dissection. Most patients tolerated manipulation of the heart during OPCAB well. Four patients developed hemodynamic instability which could not be corrected and required conversion to CPB. Two of these patients had a rise in pulmonary artery pressure and hypotension when the heart was positioned for grafting the Obtuse Marginal arteries. The remaining two patients had ventricular tachycardia and ventricular fibrillation with hemodynamic collapse during OPCAB. Internal cardiac massage was given and emergency CPB instituted to complete the operation.

Use of multiple inotropic drugs and IABP in the immediate postoperative phase was less in the OPCAB group (23.4% versus 39% and 1.5% versus 6% in OPCAB and CABG respectively). Average postoperative intubation time in the OPCAB group was 3.3 hour compared to 9.6 hour in the CABG group. Complications are shown in Table 3. Blood loss and reoperation rate for bleeding were lower in the OPCAB group. In the CABG group, 83% patients were given platelet transfusions. A mean of 3.2 red cell transfusions per patient was required to keep haemoglobin of 10g/dl. 56% patients in

Table 2**Intra-operative comparison OPCAB versus CABG**

Parameter	OPCAB	CABG
No of anastomoses	563 (192 patients)	608 (200 patients)
Operating time		
1 graft	86 minutes	98 minutes
2 grafts	125 minutes	110 minutes
3 grafts	183 minutes	143 minutes
4 grafts	229 minutes	119 minutes
5 grafts	253 minutes	230 minutes
Average time per anastomosis	13 minutes	7 minutes
Use of inotropes		
Vasodilator only	26 (13.5%)	7 (3.5%)
One inotrope	129 (67.1%)	115 (57.5%)
More than 1 inotrope	45 (23.4%)	78 (39%)
Requirement of IABP	3 (1.5%)	12 (6%)

Table 3**Complications**

Complication	OPCAB (%) (n=200)	CABG (%) (n=200)
Intubation time	3.3 hr	9.6hr
Myocardial infarction	2 (1%)	1 (0.5%)
New Atrial fibrillation	6 (3%)	23 (11.5%)
Bleeding/Blood utilization:		
Bleeding volume	426ml	672ml
Platelet transfusion	16 (8%)	165 (83%)
Packed cells	112 (56%)	162 (81%)
Other products	10 (5%)	146 (73%)
Massive transfusion	nil	4 (2%)
Reoperation	5 (2.5%)	12 (6%)
Neurological dysfunction:		
Stroke	2 (1%)	2 (1%)
Neurocognitive decline	nil	7 (3.5%)
Pulmonary dysfunction:		
Prolonged ventilation (>24 hours)	2 (1%)	6 (3%)
Pneumonia	3 (1.5%)	4 (2%)
Acute distress syndrome	nil	2 (1%)
Renal Dysfunction:		
Rise in creatinine >1mg%	15 (7.5%)	28 (14%)
Dialysis required	1 (0.5%)	2 (1%)
Gastrointestinal complications		
Bleeding	nil	1 (0.5%)
Multiorgan failure	1 (0.5%)	3 (1.5%)
Infections:		
Superficial sternal	6 (3%)	16 (8%)
Deep sternal	3 (1.5%)	4 (2%)
Leg wound	5 (2.5%)	10 (5%)
Mortality	3 (1.5%)	4 (2%)

the OPCAB group required packed cell transfusions with a mean of 1.2.

Units per patient and only 8% needed platelet infusion. There was no incidence of bleeding diathesis or requirement of massive transfusion in this group.

Incidence of stroke was comparable in the two groups.

Neurocognitive decline in the form of disorientation, agitation, frank psychosis and delirium was seen in seven patients (3.5%), however no patient in the OPCAB group had this complication.

Incidence of prolonged ventilation (3%), acute respiratory distress syndrome (1%), postoperative renal dysfunction (15%) and atrial fibrillation (11.5%) was higher in the CABG group as compared to OCAB. Perioperative myocardial infarction in the form of fresh changes in the electrocardiogram accompanied by serial rise in creatine kinase-MB levels, was seen in two patients (1%) who underwent OPCAB and one patient (0.5%) in the CABG group. None of these patients required any additional intervention.

Overall mortality was same in both groups (1.5% OPCAB versus 2% CABG). However, only 1 (0.5%) out of 192 patients who underwent successful OPCAB died. This patient was a 68 year old male with recent myocardial infarction, unstable angina, renal dysfunction and diffuse coronary artery disease. Two OPCAB patients who required conversion to CPB on account of hemodynamic collapse needed IABP support and prolonged ventilation in the post operative period. One had persistent low cardiac output leading to multiorgan failure and death on third postoperative day. The second recovered well but developed deep mediastinal infection and died 30 days after surgery. There were four (2%) deaths in the CABG group. One patient was in a critical preoperative state (euroSCORE 8), one developed acute respiratory distress syndrome after massive blood transfusion, one had gastrointestinal haemorrhage from a duodenal ulcer and one died of acute renal failure.

Discussion

OPCAB is often regarded as a recent advancement, however, the history of coronary surgery reveals that many initial procedures were performed on the beating heart [2-4]. Kolessov [5] reported using the LIMA for coronary bypass without the pump in 1967. Favaloro [6] in 1968, popularised coronary artery bypass with saphenous vein grafts using pump support. First reports of off pump coronary bypass procedures were presented in 1975 [7,8]. These authors concluded that the LAD and the RCA could be bypassed using a simple four traction suture technique with a mortality of 4.5%. As perfusion technology and myocardial protection strategies developed, most surgeons abandoned off-pump surgery in favor of having the advantage of operating on an arrested heart in a dry field. Conventional CABG has for many years represented the gold standard of coronary revascularization. However, the use of CPB is associated with numerous complications [9,10]. During CPB blood is exposed to synthetic, non-endothelial surfaces of the circuit and is subjected to mechanical forces generated by the heart lung machine. This results in damage to the formed elements and alteration in components of the thrombotic, fibrinolytic and

complement systems [11,12]. A whole body inflammatory response is initiated which has deleterious affects on all organ systems to varying degrees, potentially leading to dysfunction and/or damage of the brain, lungs, heart, kidneys, and coagulation system [13]. Embolization of air, atherosclerotic debris or particulate matter from the aorta, heart chambers, or the bypass circuit is another source of complications arising from CPB.

Excessive postoperative bleeding, acute renal failure, cardiac dysfunction, lung impairment, neurological complications, atrial fibrillation and wound infection are important causes of morbidity and mortality after CPB [14]. Allogenic blood products are often required to correct haemostatic function. 3 to 5% of patients require surgical re-exploration for bleeding [15]. Stroke occurs in 1 to 3% of patients undergoing CABG while psychiatric manifestations and cognitive impairment occurs more often [16].

Occurrence of acute renal failure ranges from 1 to 30% depending on the population studied and the definitions used [17,18]. Pulmonary impairment after cardiac surgery is multifactorial. Atelectasis, increased intrapulmonary shunting, alterations in lung and chest wall mechanics are common to both OPCAB and conventional CABG. However, CPB induced inflammatory response causes further damage by producing increased pulmonary endothelial permeability, parenchymal damage, and changes in the composition of alveolar surfactant [19-21]. Atrial fibrillation (AF) is the most common complication of CABG occurring in 15 to 20% of patients [22]. It predisposes the patient to embolic complications affecting morbidity, hospital stay, and financial resources. Incidence of postoperative AF is lower after OPCAB [23,24].

By avoiding CPB, OPCAB removes an important factor in the pathogenesis of most of these complications. Organ functioning and haemostasis are better preserved, leading to a lesser incidence of complications and a large reduction in cost of management.

Results from double-blind, randomized controlled trials (RCTs) are regarded as the best evidence to ascertain the value of a particular therapy. In 2005, Raja et al [25] evaluated evidence from 67 published reports of RCTs to determine the impact of OPCAB on 12 outcomes. They concluded that, compared to conventional CABG, OPCAB is associated with lower morbidity rates, similar graft patency, and substantially lower costs.

In the present study similar trends were noticed in transfusion requirement, neurocognitive dysfunction, renal and pulmonary complications in the patients who underwent OPCAB. 192 patients out of 200 (96.2%)

could be operated successfully without using CPB with a mortality of 0.5% and minimum morbidity while 2 out of 8 patients (25%) who required conversion from OPCAB to CPB died.

Conclusion

OPCAB is safe, effective and can be offered to more than 90% patients as the primary strategy for surgical myocardial revascularization. It has lower overall morbidity than conventional CABG mainly because it avoids the whole body inflammatory response of cardiopulmonary bypass and preserves organ functioning better. Its main limitations are hemodynamic instability caused by manipulation of the heart, arrhythmias and inability to find a deeply embedded target vessel. These factors affect the outcome adversely making conventional CABG a better option in these situations.

Conflicts of Interest

None identified

Intellectual Contribution of Authors

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