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Clinical Outcome of CABG on Off-pump Beating Heart and On-pump Beating Heart: Experience in Ibrahim Cardiac Hospital & Research Institute (ICHRI)

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ABSTRACT

Background: To avoid harmful effect of cardiopulmonary bypass (CPB) used in off-pump coronary artery bypass graft (CABG) surgery, cardiac surgeons are now inclined to on-pump beating heart surgery (ONBEAT). However, the superiority of ONBEAT over Off-pump has not yet been conclusively established. This study compares the outcomes between off-pump and on pump beating heart CABG surgery.

Methods: A total 249 consecutive patients who underwent non-emergency, primary isolated CABG from January 2014 to December 2017 by a single surgeon were included. The selected patients were assigned to either OPCAB group (Patients who received Off-pump beating heart CABG surgery, n=193) or to ONBEAT group (patients who received On-pump beating heart CABG surgery, n=56). The clinical outcomes were investigated and compared.

Result: Forty percent of the patients were in their 5th decade of life. A male predominance was also observed. The two study groups were almost identical in terms of age and sex (p=0.983 and p=0.153 respectively). None of the conventional risk factors of ischemic heart disease (smoking, diabetes, hypertension and dyslipidaemia) were any different between the study groups (p > 0.05). Cerebrovascular disease, recent MI, congestive heart failure and left main disease were significantly higher in the on-pump beating heart group compared to those in the off-pump beating heart group (p < 0.05). The left ventricular ejection fraction (LVEF) was significantly lower in the former group than that in the latter group (p= 0.007). Both groups required 3 grafts on an average. Two patients in the on-pump group required Intra-Aortic Balloon Pump (IABP) support as opposed to none in the off-pump group (p=0.050). The mean cardiopulmonary bypass (CPB) time was 105.8 ± 46.5 in the on-pump group. Fourteen patients (25%) from off-pump group needed urgent switching to on-pump group. Postoperative drainage in the first 24 hours was significantly voluminous in the on-pump group (p < 0.001). The incidence of pneumonia, respiratory failure, arrhythmia, renal failure requiring haemodialysis and perioperative MI were significantly higher in the on-pump group (p < 0.001, p < 0.001, p=0.037, p < 0.001 and p=0.050 respectively). The patients with prolonged mechanical ventilation were also more in the on-pump group. The left ventricular ejection fraction (LVEF) was much lower and Intensive Care Unit (ICU) stay was longer in the on-pump group compared to those in the off-pump group (p < 0.001). The incidence of in-hospital mortality was also higher in the former group (p=0.037).

Conclusion: OPCAB was associated with lower operative morbidity compared to ONBEAT cardiac surgery. However, the increased morbidity in ONBEAT group might have been influenced by a sizable proportion of patients from OPCAB group being switched to ONBEAT group due to their haemodynamic deterioration and frequent ventricular fibrillation. But on-pump CABG can be performed safely on high risk patients. Use of cardiopulmonary bypass and elimination of cardioplegic arrest may be beneficial to hemodynamically unstable patients.

Key words: Clinical Outcome, CABG, Off-pump Beating Heart, On-pump Beating Heart etc.

ORIGINAL ARTICLE

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INTRODUCTION

Coronary artery bypass graft (CABG) surgery is the preferred revascularization strategy for multi-vessel coronary artery disease. However, it is not without risk of mortality and severe morbidity. Although the first coronary artery bypass graft (CABG) procedures were performed in the 1960 on beating heart, refinement of the cardiopulmonary bypass pump led to the widespread use of this technology for CABG surgery beginning in 1968. However, various complications of CABG surgery including cerebral injury & stroke,[1,2] perioperative renal dysfunction,[3,4] systemic inflammatory response[5] myocardial dysfunction[6] & pulmonary complication[7,8] attributed to cardiopulmonary bypass pump in the past few decades have prompted cardiac surgeons to re-examine the safety and efficacy of CABG surgery performed on a beating heart.[9,10] Off pump CABG surgery (OPCAB) refers to CABG performed typically with sternotomy, without cardiopulmonary bypass, on a beating heart. In the United States the society of thoracic surgeons (STS) reported an off-pump CABG frequency of 9.9% between 1998 and 1999 but this proportion had increased to 25% for isolated CABG in 2001.[11] The proportion of OPCAB in CABG dramatically increased up to 63% in 2008 according to the annual report from Japanese association for cardiac surgery.[12] This is because off-pump CABG has been developed along with the advancement in devices[13] to avoid deleterious effects of extracorporeal circulation.[14] However, there might be a tendency for cardiac surgery to choose on- pump beating CABG in high risk patients, especially in patients with hemodynamic instability.[15]

Despite avoiding the disadvantages resulting from cardioplegic arrest and aortic cross clump, on-pump beating heart CABG is associated with post-operative morbidities related to the use of cardio-pulmonary bypass.[16] The systematic inflammatory reaction initiated by the extracorporeal circuit results in mechanical trauma to blood, activation of various immunological cascades (compliment, cytokines), impaired homeostasis, neurological, renal & gastrointestinal dysfunction.[17] Furthermore, aortic cannulation and CPB can result in micro- and macro-embolization, with subsequent neurological and other end-organ injuries, including global myocardial ischemia, reperfusion injury etc.[18] That purpose the present study was intended to compare the outcome between off-pump beating heart and on-pump beating heart CABG in order to determine which of the two procedures is better in terms of short-term outcome.

METHODS:

This single center prospective study was conducted on 249 consecutive patients who underwent non-emergency isolated CABG surgery by a single surgeon at Ibrahim Cardiac Hospital & Research Institute between January 2014 to December 2017. The patients had graftable double or triple vessel disease. Exclusion criteria included concomitant left ventricular aneurysm, concomitant post infarction. ventricular septal defect, concomitant moderate to severe mitral regurgitation & aortic regurgitation and concomitant acquired or congenital cardiac or aortic surgery. The patients were divided into 2 groups – Group-I, who were operated on without cardiopulmonary bypass (OPCAB group) & Group-II who received on-pump beating heart CABG surgery or (ONBEAT group). The decision to perform on-pump beating or off-pump beating CABG was influenced by each patient's demographic and clinical profile (e.g. age, diabetes mellitus, renal dysfunction, left ventricular ejection fraction and estimated surgical risk) but the final choice was dependent on discretion of the cardiac surgeon, since in our center, off-pump CABG has been performed routinely for over 6 years.

All off-pump and on-pump beating CABG procedures were performed by a single surgeon who is highly experienced in both off-pump and on-pump beating CABG surgery. Data pertaining to peroperative, intraoperative & post-operative variables (age, sex, weight, smoking, hypertension, diabetes, hyperlipidaemia, cerebrovascular disease (CVD), chronic obstructive pulmonary diseases (COPD), chronic heart failure, renal dysfunction, recent myocardial infarction, extent of coronary artery disease, peripheral vascular disease, left main disease, history of myocardial infarction, left ventricular ejection

fraction, congestive heart failure etc.) were collected using a structured questionnaire. The main outcome measures were in-hospital mortality, IABP (as and when needed basis), neurological deficit (stroke), post-operative renal failure, pneumonia, duration of ventilator support, drainage during first 24 hours, perioperative MI, length of ICU stay.

In-hospital mortality was defined as death within the same hospital in which the CABG was done regardless of causes. Postoperative neurological deficit was defined as a new focal neurological deficit & comatose states occurring postoperatively and persisted for > 24 hours after its onset and was noted before discharge. Post-operative myocardial infarction was defined as appearance of a new Q-wave during postoperative period in two or more contiguous leads on an Electrocardiogram or significant rise in postoperative cardiac enzymes. Postoperative bleeding was defined as bleeding that required surgical re-exploration in operating theater. Intraoperative low cardiac output syndrome was defined as the requirement for intraaortic balloon pump (IABP). Post-operative pneumonia was defined as presence of pathogenic microorganism in sputum culture requiring antibiotics or an X-ray chest diagnosing pneumonia following cardiac surgery. Prolonged ventilation was defined as mechanical ventilation (MV) >12 hours. Post-operative respiratory failure was defined as duration of mechanical ventilation for more than 72 hours or reintubation following cardiac surgery. Wound infection was considered if any drainage material or discharge from the sternotomy wound was purulent. Patients were installed with an IABP when they were unable to discontinue cardiopulmonary bypass or developed low cardiac output after CABG surgery.

Statistical analysis was performed with SPSS (Statistical Package for Social Sciences), version 17. Categorical data were expressed as frequency with corresponding percentage, while continuous data were presented as mean value ± SD, or median and range. Dichotomous variables were compared between study groups using Chi-square (χ^2) Test and continuous variables were compared using Student's t-Test. The level of significance was set at 5% and a probability value (p-value) of < 0.05 was considered significant.

SURGICAL PROCEDURE:

All patients underwent CABG through median full sternotomy, the in situ left internal mammary artery. The procedure is always preferred as the first choice for revascularization of the left anterior descending coronary artery territory. Saphenons vein graft was harvested with an open technique. For patients receiving off-pump CABG, heparin was given to reach activated clotting time (ACT) of more than 300 second. The central temperature was maintained above 36°c to avoid hypothermia induced ventricular arrhythmia. The heart was displaced using a posterior pericardial sling and gauze swabs. For good presentation of the target arteries on the lateral and inferior aspect of the heart patients were placed in right decubitus Trendelenburg position. Stabilization of target coronary arteries was accomplished with this stabilizer. A CO_2 blower was used for a bloodless field. An intra-coronary shunt was used in all patients to maintain coronary flow thereby reducing myocardial ischemia & at the same time minimizing bleeding from the coronary arteriotomy.

For patients undergoing on-pump beating heart CABG, cardiopulmonary bypass was instituted by cannulating the ascending aorta and right atrium after systemic heparinization (3 mg/kg body weight) with a target activated clotting time more than 400s without either cardioplegic arrest or an aortic cross-clamp. Moderate haemodilution (hamatocrit 20 to 25%) and no cooling were used during cardiopulmonary bypass. Standard management included membrane oxygenators, arterial catheter filters & a non-palsatile flow of 2.4 L/min/m^2 with a mean arterial blood pressure greater than 60 mm Hg. The same exposure, stabilization and immobilization technique were used to allow exposure of the lateral, posterior and inferior walls of the heart during grafting. The left anterior descending (LAD) artery was usually grafted first, for the grafting of this artery was achieved without much displacement of the heart and without much hemodynamic compromise. Distal anastomosis was performed with continuous 7-0 or 8-0 polypropylene (prolene)

monofilament suture. Proximal anastomosis was performed with 6-0 continuous prolene suture. After discontinuation of cardiopulmonary bypass heparin was neutralized with 1 mg protamine sulphate per 1 kg provided.

RESULTS:

Forty percent of the patients were in their 5th decade of life. A male predominance was also observed. The two study groups were almost identical in terms of age and sex (p=0.983 and p =0.153 respectively) (Table I). None of the conventional risk factors of ischemic heart disease (smoking, diabetes, hypertension & dyslipidaemia) were any different between the study groups (p>0.05). Cerebrovascular disease, recent MI, congestive heart failure and left main disease were significantly higher in the on-pump beating heart group compared to that in the off-pump beating heart group (p < 0.05). The left ventricular ejection fraction (LVEF) was significantly lower in the former group than that in the latter group (p = 0.007) (Table II). Both groups required 3 grafts on an average. Two patients in the on-pump group required IABP support as opposed to none in the off-pump group (p=0.050). The mean cardiopulmonary bypass (CPB) time was 105.8 ± 46.5 in the on-pump group. Fourteen patients (25%) from off-pump group needed urgent switching to on-pump group (Table III).

TABLE I. Distribution of demographic characteristics between the study groups

Demographic characteristics*	Group		p-value
	On-pump (n = 56)	Off-pump (n = 193)	
Age* (years)			
< 50	13(23.2)	44(22.8)	0.983
50 – 60	22(39.3)	78(40.4)	
≥ 60	21(37.5)	71(36.8)	
Sex			
Male	47(83.9)	175(90.7)	0.153
Female	9(16.1)	18(9.3)	

Figures in the parentheses indicate corresponding %;
***Chi-squared Test (χ^2)** was done to analyze the data.

TABLE II. Distribution of risk factors and clinical characteristics between groups

Risk factors and clinical characteristics	Group		p-value
	On-pump (n = 56)	Off-pump (n = 193)	
Recent smoking*	13(23.2)	34(17.6)	0.346
Hypertension*	40(71.4)	141(73.1)	0.810
Diabetes*	34(60.7)	123(63.7)	0.681
Overweight & obese	52(53.6)	88(45.6)	0.599
Hyperlipemia/DL*	47(83.9)	156(80.8)	0.599
Cerebrovascular disease (CVD) *	4(7.1)	2(1.0)	0.009
Peripheral vascular disease**	0(0.0)	2(1.0)	0.600
Chronic pulmonary disease (COPD)*	3(5.4)	11(5.7)	0.922
S. Creatinine (Pre-operative) *	1.2 ± 0.3	1.1 ± 0.3	0.074
Chronic heart failure*	14(25.0)	30(15.5)	0.102
Recent MI*	32(57.1)	74(38.3)	0.012
Congestive heart failure*	7(12.5)	8(4.1)	0.021
Extent of CAD*			
1 vessel	0(0.0)	10(5.2)	0.082
2 or more vessel	56(100.0)	183(94.8)	
LM disease*	19(33.9)	41(21.2)	0.051
LVEF (%)#	49.4 ± 8.6	53.2 ± 9.2	0.007

Figures in the parentheses indicate corresponding %;
***Chi-squared Test (χ^2)** was done to analyze the data.
Data were analyzed using **Unpaired t-Test** and were presented as **mean ± SD.**
****Fisher's Exact Test** was done to analyzed the data.

TABLE III. Comparison of peroperative findings between groups

Peroperative variables	Group		p-value
	On-pump (n = 56)	Off-pump (n = 193)	
Number of grafts#	3.1 ± 0.6	2.8 ± 0.8	0.407
IABP support**	2(3.6)	0(0.0)	0.050

Figures in the parentheses indicate corresponding %;
Data were analyzed using **Unpaired t-Test** and were presented as **mean ± SD.**
****Fisher's Exact Test** was done to analyze the data.

Postoperative drainage in the first 24 hours was significantly voluminous in the on-pump group than that in off-pump group (p < 0.001). The incidence of pneumonia, respiratory failure, arrythmia, renal failure requiring haemodialysis and perioperative MI were significantly higher in the former group (p < 0.001. p < 0.001, p = 0.037,

p < 0.001 and p = 0.050 respectively). The patients with prolonged mechanical ventilation were also more in the former group [mechanical ventilation (MV) > 12 hours]. The left ventricular ejection fraction (LVEF) was much lower and ICU stay was longer in the on-pump group compared to those in the off-pump group (p < 0.001). The incidence of in-hospital mortality was also higher in the on-pump group (p = 0.037) (Table IV).

TABLE IV. Comparison of outcome between groups

Outcome variables	Group		p-value
	On-pump (n = 56)	Off-pump (n = 193)	
Drainage in first 24 h (ml)#	384.9 ± 103.7	195.3 ± 71.2	< 0.001
Pneumonia*	15(26.8)	3(1.6)	< 0.001
Respiratory failure*	13(23.2)	4(2.1)	< 0.001
Stroke**	0(0.0)	1(0.5)	0.775
Arrythmia**	21(37.5)	2(1.0)	< 0.001
Mediastinitis**	1(1.8)	0(0.0)	0.225
Renal failure needing hemodialysis**	3(5.4)	1(0.5)	0.037
Duration of MV (>12 h)*	35(62.5)	4(2.1)	< 0.001
LVEF before discharge (%)#	50.0 ± 9.1	56.5 ± 8.0	< 0.001
ICU stay (days)#	3.8 ± 1.3	3.4 ± 0.8	0.007
Perioperative-MI**	2(3.6)	0(0.0)	0.050
In-hospital mortality**	3(5.4)	1(0.5)	0.037

Figures in the parentheses indicate corresponding %;
***Chi-squared Test** (χ^2) was done to analyze the data.
Data were analyzed using **Unpaired t-Test** and were presented as **mean ± SD.**
****Fisher's Exact Test** was done to analyzed the data.

DISCUSSION:

There is continuing debate as to impact of OPCAB on CABG operative mortality. Studies suggest that OPCAB has a protective effect.[8,19] Our analysis also showed that intraoperative conversion from OPCAB to ONBEAT had increase in operative mortality. This finding is consistent with previous studies that reported higher mortality in patients undergoing conversion from OPCAB to ONBEAT CABG surgery.[20-22] The process of conversion itself may confer an increased risk of complication. However, as this study reported the experience of a single-center, single surgeon and, therefore, may not be generalizable.

Due to hemodynamic deterioration and frequent ventricular fibrillation during off-pump CABG surgery 14 patients had to be switched urgently to on-pump beating heart CABG surgery. Out of 14 patients 2 died of low cardiac output and malignant arrhythmia and 1 patient died due to pneumonia in the postoperative period. Several authors have, however, reported that hemodynamic collapse and emergent conversion to cardiopulmonary bypass from off-pump CABG is associated with poor prognosis.[23]

The major finding of this study was that patients in OPCAB group compared to the ONBEAT group received decreased amount of drainage during the first 24 hours, and a more improved left ventricular ejection fraction (LVEF), decreased in-hospital mortality and reduced incidence of major operative morbidity; while ONBEAT group because of increased amount of drainage during first 24 hours required blood transfusion. The reason may be related to cardiopulmonary bypass and more heparinization during on-pump beating CABG surgery. The ONBEAT group compared to the OPCAB had a higher incidence of postoperative pulmonary complication like pneumonia, which might be related to the application of extracorporeal circulation during on-pump beating heart surgery. The risk and severity of acute lung injury have been consistently linked to the duration of CPB. Severe lung injury following CPB has been associated with a 50% mortality.[24]

Lesser degree of lung injury after CPB such as reduced oxygen index, increased ventilation perfusion mismatch and decreased lung compliance are seen in up to 12% of patients. Pulmonary injury is detectable even following uncomplicated CPB using sensitive measures of lung injury.[25,26] Duration of prolonged mechanical ventilation was significantly higher in ONBEAT group. Theoretically, avoiding cardiopulmonary bypass should translate into less postoperative pulmonary dysfunction. Most randomized control trials show a definitive reduction in duration of ventilation, with early extubation after OPCAB. Patients of preexisting pulmonary disease are

particularly benefited from OPCAB surgery.[27,28] Patients in the OPCAB group compared to ONBEAT group had a significantly higher early postoperative LVEF, suggesting that the inflammatory response may be involved in the pathogenesis of post CPB cardiovascular dysfunction.[29,30] The incidence of perioperative arrhythmia mostly atrial fibrillation (AF) was significantly higher in ONBEAT group. Atrial fibrillation occurs in 25-60% of patients after cardiac surgery. The role of OPCAB in influencing operative morbidity depends upon factors such as patient selection, surgeon experience and number of patients and further evaluation[31].

The etiology of postoperative AF is multifactorial and exact pathogenesis of postoperative AF in CABG patients is still not understood. However, CPB has been shown to be main independent predictor of postoperative AF in patients undergoing coronary revascularization.[32] Regional ischemia due to atrial incision, and acute or chronic myocardial hypoperfusion may contribute to the development of AF by altering atrial conduction & refractoriness.[33] Hypomagnesaemia, which frequently occurs after CPB, may induce post-operative AF.[34] Inflammatory events are also suggested to play a role in the pathogenesis of postoperative AF. The development of systemic inflammatory response syndrome (SIRS) with or without clinically proven infection has been shown to be an independent risk factor for new onset of tachyarrhythmias in particular AF, after cardiac surgery.[35] Off-pump coronary bypass reduce the incidence of postoperative AF compared with CABG on cardiopulmonary bypass.[36-40] This is probably secondary to the blunted systemic inflammatory response, avoidance of atrial cannulation, and reduce myocardial ischemia in OPCAB.

In more than a decade or so OPCAB has been tested through an increasingly rigorous process of scientific validation. From a large number of observational, case-matched, retrospective analysis to randomized controlled trials, there is plenty of evidence that OPCAB surgery is now proven, safe cost-effective and reproducible surgical technique. Finally, as the study was done in a single center by single surgeon, caution should be exercised to generalize the findings to reference population.

CONCLUSION:

OPCAB was associated with lower operative morbidity compared to ONBEAT cardiac surgery. However, intraoprative conversion from OPCAB to ONBEAT CABG significantly increases operative morbidity & mortality, because haemodynamically unstable patients or patients with frequent ventricular fibrillation are often switched to ONBEAT group. But on-pump CABG can be performed safely on high risk patients. Use of cardiopulmonary bypass and elimination of cardioplegic arrest may be beneficial to hemodynamically unstable patients. The study indicated that OPCAB is associated with a significant reduction in blood loss and transfusion requirement, better myocardial function, reduced incidence of post operative arrhythmia, less post operative pulmonary dysfunction and pneumonia.

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