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Intracoronary Shunt in Off-Pump Coronary Artery Bypass Graft

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Abstract: This study was performed to compare the early postoperative results of off Pump Coronary Artery Bypass Graft (OPCABG) with or without using Intra Coronary Shunt (ICS). We randomized 208 patients scheduled for OPCABG into shunt group (group 1, n = 104) and no-shunt group (group 2, n = 104). The two groups were well matched according to the age, gender, angina class, New York Heart Association (NYHA) functional class, or operative priority and disease severity. Peri- and post-operative changes in electrocardiography, wall motion abnormality in echocardiography, rate of myocardial infarction, mortality, morbidity, cardiac enzymes and ICU stay were recorded. There was no significant difference between two groups in changes of electrocardiography, myocardial infarction, left ventricular ejection fraction (LVEF), in hospital mortality and ICU stay but Creatine Kinase Myocardial Band (CK-MB) enzyme was higher in no shunt group, while troponin-I was increased in shunt group. Preoperative LVEF was higher in no-shunt group, but postoperative LVEF was higher in shunt group ($p>0.05$). Also, the change of LVEF before and after operation in each group was not significant. Using intracoronary shunt in off pump coronary artery bypass graft leads to less change in cardiac enzymes but had no effect on perioperative and postoperative myocardial infarction, LVEF, mortality and morbidity.

Key words: Off-pump, cardiopulmonary bypass, coronary artery bypass graft

INTRODUCTION

Off pump coronary bypass graft (OPCABG) has gained increased popularity worldwide in patients with coronary artery disease (Bergsland *et al*., 2009; Pinto *et al*., 2008; Shim *et al*., 2008; Emmiler *et al*., 2008). It has theoretical and practical advantages over Conventional Coronary Artery Bypass Grafting (CCABG) (Wippermann *et al*., 2004). During OPCAB, displacing the heart for exposure of the anastomotic field can elicit a significant hemodynamic deterioration (Shim *et al*., 2008; Chassot *et al*., 2004).

Interruption of the coronary flow for precise vessel anastomosis may result in regional ischemia and myocardial dysfunction (Bergsland *et al*., 2009; Shim *et al*., 2008; Chassot *et al*., 2004; Kwak, 2005). In addition, the necessity of a bloodless field to obtain optimal visibility during performance of the anastomosis is an issue of concern in OPCABG (Demaria *et al*., 2003). Various anesthetic and surgical techniques to minimize the myocardial dysfunction and subsequent hemodynamic deterioration have been proposed (Shim *et al*., 2008; Chassot *et al*., 2004; Kwak, 2005). Among them, insertion of intracoronary shunt (ICS) has been advocated by many authors with favorable results, which provides bloodless surgical field and some degree of distal flow at the same time (Shim *et al*., 2008; Emmiler *et al*., 2008; Gürbüz *et al*., 2006; Tok *et al*., 2008). ICS has the double advantage of drying the anastomotic site (hemostatic effect) and allowing an effective distal coronary perfusion (myocardial protection), which is necessary in OPCAB surgery (Wippermann *et al*., 2004; Demaria *et al*., 2003; Yokoyama *et al*., 2004). Totally, distal anastomosis in OPCABG operations is performed in two methods including (1) using ICS and (2) not using shunt (simple local occlusion coronary artery with tape, suture or bulldog). Although, the use of ICS has been proposed as a key to successful OPCABG (Bergsland *et al*., 2009; Tavakoli *et al*., 2005; Sepic *et al*., 2003), it is not preferred by all surgeons, mainly because of its technical difficulties. The positioning of this tiny material into the small coronary artery through a limited arteriotomy has

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been considered troublesome and time wasting (Yokoyama *et al*., 2004; D'Ancona *et al*., 2001). More frequent use of ICS may facilitate OPCABG by minimizing ischemia and hemodynamic compromise (Sepic *et al*., 2003).

In this study we reported this experiences in the comparison of OPCABG with or without ICS. The purpose of this study was to evaluate the role of ICS during OPCABG surgery.

MATERIALS AND METHODS

The clinical trial was conducted in Tabriz Shahid Madani Heart Center. Between March 2005 and September 2006 we studied 208 consecutive patients undergoing OPCABG. Inclusion criteria were adult patients with severe Coronary Artery Disease (CAD) scheduled for elective or urgent myocardial revascularization by OPCABG. The patients fulfilling the above criteria were randomized into either of two groups based on use or not use of intracoronary shunt: Group A (with shunt, n = 104) and Group B (without shunt, n = 104). The study was approved by the Regional Ethics Committee. Patients signed informed consent before the operation.

All participants were evaluated preoperatively and the baseline information was obtained including risk factors (DM, hypertension, hyperlipidemia, familial history, smoking, previous MI), age, sex, weight, extension of vessel stenosis and location of stenosis. Also, clinical findings (severity of angina and dyspnea), ECG and echocardiography (LVEF, wall motion) changes and enzyme changes (creatine kinase-MB, troponin-I) in different times, number of grafts, duration of postoperative ventilation, rate of mortality and morbidity and neural complications were recorded.

Operative technique: Study was performed in 70% or more stenotic coronary arteries in biplane coronary angiography. All the surgical procedures were performed by one surgeon experienced in OPCABG. At first, premedication was 5 to 10 mg diazepam taken orally; then, anesthesia was induced with 2 to 5 (μg kg^{-1}) fentanyl, thiopentone 2 to 5 (mg kg^{-1}) and 0.15 mg kg^{-1} cisatracurium. Repeated doses of fentanyl and sevoflurane 1.0 to 2.5% maintained anesthesia. Also, heparin was given to maintain activated clotting time above 250(S) (Bergsland *et al*., 2009). Preparation of patients for operation included median sternotomy which allows the surgeon to visualize the operative field from an orientation that is familiar and similar to on-pump procedures. This facilitates identification of target vessel as well as harvesting of the internal mammary arteries for use as conduit (Cohn, 2008). For optimal target vessel exposure that is essential for successful OPCABG, we needed two approaches to manipulate the heart and expose. One method was the deep traction suture and another was using stabilization device (Octapus, Starfish). At first, proximal control of the vessel selected for grafting was obtained with bulldog in the 3-5 min (ischemic preconditioning effect). Then, in the absence of hemodynamic or electrocardiographic changes, we continued the operation (Bergsland *et al*., 2009; Cohn, 2008).

In the first group (with ICS), after proximal control of the vessel selected with bulldog and following coronary arteriotomy by a microknife, the bulldog clamp is used to decrease the blood leakage for a visible extension of the coronary arteriotomy with scissors. Then, ICS (flexible, nontoxic) was employed in way that the long arm of the shunt is introduced into the proximal coronary artery while loosening the clamp. Once the long arm passes the clamp site, the clamp is closed again so that the long arm hold in the proximal coronary artery. Then, the short arm is introduced into the distal coronary artery while the bulldog clamp prevents an escape of the long arm. Holding the short arm next to the bulb with a ring-tipped forceps blocks the intrashunt blood flow; this allows clear visualization of the distal coronary arteriotomy. Once both arms are placed in the coronary artery, the position of the shunt can be adjusted while the clamp is used. The clamp was removed when the blood leakage from the arteriotomy was negligible (Yokoyama *et al*., 2004; Shim *et al*., 2008; Bergsland *et al*., 2009).

In other groups (simple local occlusion), after proximal control of the vessel selected with bulldog we avoid distal occlusion because of potential damage to the intima of the outflow portion of grafted artery. Distal occlusion can be placed if back bleeding from collateral vessel is problematic. In all stages of the procedure and at the end of the operation, ECG changes were recorded; the anticoagulation is reversed with half of full-dose protamine sulfate (Shim *et al*., 2008; Bergsland *et al*., 2009; Cohn, 2008). All the patients were followed up by echocardiography, electrocardiography and cardiac enzymes early after operation.

Statistical analysis: The collected data were expressed as percentage and Mean±SD. Continuous (quantitative) variables were compared by Student t-test (Independent samples) or ANOVA ONE way. Categorical (qualitative) variables were compared by contingency tables and Chi-square test or Fisher's exact test. The p-value$\leq$0.05 was considered statistically significant.

RESULTS

Of 208 studied patients, 104 patients were randomly assigned to shunt (group A) and 104 to no shunt (group B). Eighty patients (77%) in group A and 78 patients (75%) in group B were male (p>0.05). All patients underwent OPCAB through median sternotomy. All of achieved information was classified as three parts including pre-operative, intra-operative and post-operative:

Pre-operative data: Table 1 shows the baseline information of patients in two groups. As showed in Table 1 we did not detect any significant difference between the studied variables in both groups.

There were not any significant differences in NYHA class and other preoperative characteristics in the two groups (Table 2).

Intra-operative data were recorded during operation including ECG changes. We found three patients (2.9%) in group A and three patients (2.9%) in group B with ECG changes in LAD region (p>0.05). There was one case (0.96%) with ECG changes in RCA region in group A but there was not in group B (P>0.05). Any patient in each group had not ECG changes in LCX region.

Post-operative data: were included ECG, regional wall motion abnormality, ejection fraction and cardiac enzymes changes. We found one patient (0.96%) in group A and five patients (4.9%) in group B with ECG changes in LAD region (p>0.05). There was one case with ECG changes in RCA region in group B but there was not in group A (p>0.05). Any patient in each group had not ECG changes in LCX region. ECG changes were not significantly different between two groups.

Also, the mean ejection fraction in two groups was 35-45% without any significant difference (Table 3). The postoperative echocardiographies also did not reveal hemodynamic deterioration in both groups. Cardiac enzymes changes (CPK-MB and CTN-I) were recorded in 3, 12 and 36 h after operation (Table 3). CK-MB levels in 3 and 12 h after operation were significantly higher in group B (Table 1) but in 36 h after operation was not significantly different in two groups (p = 0.167). CTN-I level in 3 h after operation was significantly higher in group A (p = 0.001) but in 12, 36 after operation was not significantly different in two groups (Table 1). The ICU stay, intubation time and in-hospital mortality were not significantly different between two studied groups (p>0.05).

Table 1: Comparison of demographics and perioperative data of patients in two groups

Variables	Group A (with shunt)	Group B (without shunt)	p-value
Average age (Year)	60±10	55±10	>0.05
Average weight (kg)	73±11	73±11	>0.05
Diabetes mellitus	46%	54%	>0.05
Hyperlipidemia	50%	50%	>0.05
Hypertension	54%	46%	>0.05
Smoking	47%	53%	>0.05
Family history of CAD	42%	58%	>0.05
ECG findings			
Anterior MI	52%	48%	>0.05
Posterior MI	39%	62%	>0.05
Preoperative LVEF	45.3%	45.8%	>0.05

CAD: Coronary artery disease; ECG: Electrocardiography; LVEF: Left ventricular ejection fraction

Table 2: Comparison of Angina severity, NYHA class and artery involvement before operation in two groups

Variables	Group A (with shunt) (%)	Group B (without shunt) (%)	p-value
Angina severity			
I	2	6	>0.05
II	14	14	
III	83	80	
NYHA function class			
I	0	0	>0.05
II	80	77	
III	13	16	
IV	7	7	
Artery involvement			
LAD	90	89	>0.05
LCX	90	85	>0.05
RCA	89	85	>0.05

NYHA: New York Heart Association, LAD: Left anterior descending artery, LCX: Left circumflex artery, RCA: Right coronary artery

Table 3: Comparison of postoperative data in two groups

Variables	Group A (with shunt)	Group B (without shunt)	p-value
Postperative LVEF	42.33	43.70	0.634
CKMB 3 h after operation	33.11	43.47	0.010
CKMB 12 h after operation	40.19	51.87	0.018
CKMB 36 h after operation	35.72	38.34	0.167
CTNI 3 h after operation	2.55	1.57	0.001
CTNI 12 h after operation	2.74	3.09	0.254
CTNI 36 h after operation	2.25	2.32	0.864
ICU stay after operation (h)	59.60	58.90	0.425
Intubation time (h)	11	10	0.7
Mortality	1%	1%	>0.05

LVEF: Left ventricular ejection fraction, CKMB: Creatine kinase myocardial band, CTNI: Cardiac troponin I

DISCUSSION

Local occlusion of human coronary arteries during beating heart coronary surgery may cause endothelial denudation, local microthrombosis, atherosclerotic plaque rupture and injury to target vessel side branches (Wippermann *et al*., 2004; Hangler *et al*., 2001). During OPCABG, control of bleeding from the target vessel is either achieved by external compression with loops and sutures or insertion of an intraluminal shunt (Perrault *et al*., 2000; Hangler *et al*., 2008). Any occlusion technique, such as snares and clamps, carries a potential risk of endothelial injury (Yokoyama *et al.*, 2004; Hangler *et al.*, 2001). The use of snaring of the native vessel should preferably be avoided (Bergsland *et al.*, 2009). In a study by Hangler *et al.* (2001), coronary arteries of 17 patients undergoing heart transplantation were locally occluded after starting CPB. Immediately after excision of the diseased heart, the vessels were fixed. Scanning electron microscopy revealed significantly more severe endothelial injury in the area of occlusion than in the adjacent, not manipulated control segments. In the region of local occlusion, plaque rupture was noted in three of 34 atherosclerotic vessel specimens, injury to side branches was evident in two of 44 and local microthrombus formation was evident in six of 44 samples (Hangler *et al.*, 2001). The same changes have been reported in other studies (Wippermann *et al.*, 2004; Yokoyama *et al.*, 2004; Izzat *et al.*, 1998). An atheroma-free coronary artery without stenosis is desirable for the clamp site, avoiding the risk of plaque rupture or detachment even thought the mild-pressure micro-clamp would be applied with the surrounding fat tissue or bilateral cardiac veins to minimize the risk of coronary artery injury (Yokoyama *et al.*, 2004).

Technical improvements have made OPCABG a more attractive option for coronary revascularization (Bergsland *et al.*, 2009; Konstantinov, 2004). The OPCABG surgeon still occasionally faces myocardial ischemia and hemodynamic collapse during surgery. An ICS may prevent such events and the need for emergency initiation of CPB (Mujanovic *et al.*, 2003) and help the surgeon to perform a better anastomosis. It is possible, however, that a shunt may denude the endothelium and cause vessel damage, thrombosis or subsequent stenosis (Bergsland *et al.*, 2009; Dygert *et al.*, 2006).

However, the use of ICS remains controversial. Despite case reports showing coronary endothelial injury temporally related to OPCABG and presumably resulting from ICS, this cause and effect relationship is plausible but not consistent (D'Ancona *et al.*, 2001). Adequate and agile shunt positioning may be difficult to achieve rapidly (D'Ancona *et al.*, 2001). Opinions have been divided on whether the use of shunt is helpful in the creation of the anastomosis. The presence of a shunt may prevent the surgeon from taking too large arterial bites during suturing (Yasuda *et al.*, 2004) and may prevent bleeding and improve visibility. Studies demonstrated improved on-table angiographic results in the shunt group (Bergsland *et al.*, 2009). Studies indicate that shunt may be helpful in avoiding technical mistakes (Bergsland *et al.*, 2009; Menon *et al.*, 2002). Investigators have also demonstrated equal or improved angiographic results in shunted patients (Bergsland *et al.*, 2009; Menon *et al.*, 2002). The quality of the anastomosis is at least as good as when a shunt is not utilized (Bergsland *et al.*, 2009).

Intracoronary shunts used as hemostatic devices in OPCAB also have the advantage of allowing myocardial protection by maintaining distal coronary perfusion (Demaria *et al.*, 2003). Studies have demonstrated that shunting can prevent acute left ventricular dysfunction during beating heart coronary revascularization and is a useful tool in patients with left ventricular dysfunction or unstable angina, as well as for teaching OPCAB to residents (Gürbüz *et al.*, 2006; Ricci *et al.*, 2000). The use of ICS resulted in reduced acute ischemia and revealed wall motion abnormalities and maintained LV function. Furthermore, this technique suggests an improvement of early graft patency and a lower reintervention rate within the first 6 postoperative months. Thus, use of ICS appears to be superior to the occlusion technique early after minimally invasive direct coronary artery bypass procedures (Menon *et al.*, 2002).

Our results did not confirm the primary hypothesis that OPCABG surgery using the ICS reduced the myocardial damage during the anastomosis. The two groups were well matched according to the age, gender, primary cardiac pathology, perioperative MI and extent of coronary artery disease. However, it did successfully demonstrate that the patients who underwent OPCABG with shunt had less CK-MB leaks after surgery. In our study, we paid attention to protect myocardium in OPCABG for reducing peri-operative and post-operative complications. These considerations were using flexible shunts in shunt group to reduce the trauma during shunt insertion and avoiding Tap and bulldog insertion in distal portion following IPE in no-shunt group. Also, when we needed bulldog insertion, it was used in atheroma-free (without lesion) sites with care to take adequate tissue surrounding the vessels, as well as to use from low-pressure bulldogs.

In the study of Bergsland *et al.* (2009) to evaluate the role of intracoronary shunt during OPCABG, there were no significant differences in CK, CK-MB, C-reactive protein, aspartate aminotransferase, alanine aminotransferase, or troponin between two study groups (with or without shunt). However, they recommend the use of ICS during OPCABG surgery (Bergsland *et al.*, 2009). Tok *et al.* (2008) investigated the advantages of using ICS compared to shuntless operations. There were significant increases in serum CK levels in group 2 (shuntless operations) at postoperative 6, 12 and 24th h. In group 2, the increase of myoglobin was statistically significant at only the postoperative 24 th h. Troponin levels were significantly higher in group 2 at postoperative 6, 12 and 24 h (Tok *et al*., 2008). Gürbüz *et al* (2006) conducted the same study, in which there was no significant difference between the groups concerning the preoperative and postoperative CK and CK-MB levels. The preoperative troponin I levels of the groups were not different, whereas, postoperative levels of this marker was significantly higher in the shuntless group. They concluded that ICS reduces the postoperative troponin I levels significantly, so, it may be indicated in the patients who are thought to be susceptible to transient ischemia (Gürbüz *et al*., 2006).

We had different results in comparison with the previous studies. In our series, the endothelial injury and troponin I release were less in no-shunt group. It was probably because of the fact that we did not use bulldog in distal portions of coronary vessels or used it with taking adequate tissue surrounding the vessels. However, the differences between shunt and no-shunt group about enzyme release and endothelial injury were not statistically significant.

Pinto *et al*. (2008) analyzed the in-hospital outcome of 87 elderly patients underwent OPCABG with ICS. The mean intubation time was 18.50±19.09 h, the ICU stay was 2.92±2.03 days and hospital stay was 10.55±7.16 days. The in-hospital mortality was 4.6%. No significant differences in early mortality, ICU stay and all the postoperative clinical outcomes were observed when the two groups were compared (Pinto *et al*., 2008). The intubation time and ICU stay in Pinto *et al*. (2008) study and non-significant differences between two groups are compatible with our results. However, the mortality rate in our study was only 1% in each group.

Emmiler *et al*. (2008) evaluated ICS results between shunt group (n = 39) and shuntless group (n = 43). There were no significant differences between the groups for preoperative troponin I, CK, CK-MB and postoperative CK levels (at 6 and 24 h). Postoperative troponin I and CK-MB levels were significantly lower in the shunt group. Although, preoperative EF of the patients was not significantly different between groups, the third month EF were significantly increased in both groups and this increment was significantly higher in the shunt group than the shuntless group. One patient (2.3%) died in the shuntless group whereas, there was no death in the shunt group. They concluded that ICS has protective effects on myocardium in patients with moderate left ventricular dysfunction (Emmiler *et al*., 2008). Preoperative LVEF in our study was higher in no-shunt group, but postoperative LVEF was higher in shunt group; however, neither of these differences was significant. Also, the change of LVEF before and after operation in each group was not significant.

CONCLUSION

In the study we concluded that using intracoronary shunt in OPCAB leads to lesser changes in cardiac enzymes early postoperative but not impact on preoperative and postoperative myocardial infarction, left ventricular ejection fraction, mortality and morbidity. However, based on our experiences, we recommend using intracoronary shunt to reduce complications in OPCAB; and where the shuntless OPCABG was selected, the surgeon must always pay attention to avoid clamping of distal portions of coronary arteries, or clamp it with taking adequate tissue surrounding the vessels. In conclusion, the protective effect of the intracoronary shunt on myocardium which at least was not less than shuntless OPCAB may serve as a good indication of its usage in OPCABG surgery.

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