

Off-pump versus conventional coronary artery bypass grafting for the revascularization of posterior wall arteries

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ABSTRACT

Objectives: The aim of the present study was to investigate the feasibility of revascularization of posterior wall coronary arteries with off-pump coronary artery bypass grafting (OP-CABG) versus conventional CABG (C-CABG).

Patients and methods: Between July 2001 and October 2009, a total of 104 patients (26 males, 78 females; mean age 57±10.9 years; 43 to 74) who underwent CABG were included. The patients were divided into two groups as those undergoing revascularization with OP-CABG (Group 1, n=52) and those undergoing C-CABG. Intraoperative data and postoperative coronary angiograms at six months were recorded.

Results: The OP-CABG was associated with less requirement for blood transfusion and a lower amount of postoperative drainage. Duration of intubation and the length of stay in the intensive care unit and hospital were found to be significantly shorter in the OP-CABG group. The patency of the arterial grafts was almost completely achieved in both groups, and anastomoses on the posterior vessels were patent in the OP-CABG group.

Conclusion: Based on our experience, in properly selected cases, targeted vessels on the posterior wall can be successfully revascularized with OP-CABG.

Keywords: Beating heart, coronary artery bypass grafting, graft, patency, revascularization.

Postoperative morbidity still constitutes a common problem in patients with coexisting risk factors. Arrhythmia, ventricular dysfunction, infection, gastrointestinal dysfunction, acute pulmonary injury, and renal failure are major underlying conditions problems, contributing to the non-cardiac etiology in these patients.^[1]

Off-pump coronary artery bypass grafting (OP-CABG) has been shown to be superior to conventional coronary bypass grafting (C-CABG), since it is associated with less proteolytic and inflammatory response, decreased operative trauma, less postoperative complications, and shorter length of stay in the hospital and intensive care unit (ICU), leading to reduced morbidity and cost.^[2] Moreover, OP-CABG offers a high rate of graft patency, less amount of blood loss, lower mortality, and reduced need for inotropic support.^[2]

Owing to the fact that recent technology allows revascularization of all target vessels, OP-CABG

has become a widely used surgical modality in all patient groups. This method is preferred to avoid the deleterious effects of cardiopulmonary bypass (CPB) and is more frequently performed on the descending left and right coronary arteries (RCAs).^[3] Revascularization of coronary arteries in the posterior cardiac wall can be made only by the prominent displacement of the heart in the pericardial space.^[2,3]

In the present study, we aimed to investigate the feasibility of OP-CABG for the revascularization of posterior coronary arteries versus C-CABG and to report short-term results of this technique.

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PATIENTS AND METHODS

In this retrospective study, a total of 442 patients who underwent OP-CABG in the cardiovascular surgery department of İzmir Atatürk Training and Research Hospital between July 2001 and October 2009 were screened. Patients with a poor vascular quality or having converted to urgent CPB during OP-CABG were excluded. Finally, a total of 104 patients (26 males, 78 females; mean age 57 ± 10.9 years; 43 to 74) who underwent posterior wall bypass were included in the study. Among these patients, coronary revascularization for posterior wall arteries was carried out in 52 patients (OP-CABG Group), while another 52 patients who underwent C-CABG were included in the C-CABG group. Control coronary angiography was performed in the sixth months after the operation. Data including demographic and clinical characteristics of the patients and peri- and postoperative data were obtained from medical files. A written informed consent was obtained from each patient. The study protocol was approved by the İzmir Atatürk Training and Research Hospital Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical technique

All patients were operated by a single surgical team. Preparations for CABG was made routinely for all patients. General anesthesia was introduced with standardized intravenous narcotic anesthesia. Prior to CPB, heparin was applied at a dose of 300 IU/kg, maintaining an activated clotting time (ACT) at 450 sec. In C-CABG, ACT monitorization was performed every 15 min and additional doses of heparin were administered, if necessary. In OP-CABG, heparin (100 IU/kg) was introduced before proximal anastomosis, keeping the ACT at a range of 250 to 350 sec.

During C-CABG procedure, median sternotomy was followed by cannulation of the ascending aorta and, subsequent to two-stage venous cannulation from the right atrium, CPB was initiated. The pump flow and speed were set at a systemic pressure of 70 to 90 mmHg. Cardioplegia was continued every 20 min. Distal anastomoses were made using 7/0 prolene, while proximal anastomoses were performed with 5/0 prolene sutures along with lateral clamping. In distal anastomoses, the left anterior descending artery and

its diagonal collaterals were initially revascularized. The RCA and its branches followed by the circumflex artery and its marginal branches on posterior wall were, then, revascularized.

In order to visualize the target vessel more clearly, wet gauzes were placed posteriorly, and the heart was elevated. Suspension sutures placed on the posterior pericardium also aided as an alternative way in the elevation of heart during anterior and lateral anastomoses. On a beating heart, anastomosis was facilitated using the Octopus® (Medtronic Inc., Minneapolis, MN, USA) to provide stabilization of the myocardium.

During the anastomosis of the RCA and its branches, the traction suture was placed in a manner that the right atrioventricular junction and RCA were involved with a thick layer of the surrounding tissues. Anastomosis could be readily accomplished after stabilization of target vessels with Octopus®.

In order to preserve the hemodynamic stability, a different technique was preferred for anastomosis of circumflex artery and its marginal branches on posterior wall. Initially, the superior vena cava was freed by dissection to allow an easier manipulation of the heart. After placement of 0-silk traction suture on posterior pericardium, the patient was rotated 20 to 30° to right in the Trendelenburg position. This maneuver caused the traction of suture at the posterior pericardium and allowed the elevation of cardiac apex. At this stage, the vacuum clamp was put on the apex keeping the heart at suspension. The circumflex artery and its marginal branches were exposed readily, and anastomoses were made after stabilization of the target vessels by Octopus®. Consecutive grafting technique was not used in any of our patients.

Control coronary angiography

In our department, control coronary artery angiography is reserved for patients who underwent CABG with revascularization of circumflex artery and its marginal branches. Therefore, it has been postoperatively performed in 52 cases operated with OP-CABG and revascularization of the posterior wall.

Statistical analysis

Statistical analysis was performed using the SPSS version 10.0 software (SPSS Inc., Chicago, IL, USA).

Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency. Comparison of qualitative data was carried out using the chi-square test, while independent samples-t test was used for quantitative variables. A *p* value of <0.05 was considered statistically significant.

RESULTS

In both groups, there was male predominance; however, there was no statistically significant difference between the two sexes (*p*=0.127). The most important risk factor in both groups was smoking, lower ejection fraction (EF), and a higher incidence of chronic obstructive pulmonary disease (COPD) in the off-pump group compared to on-pump group. Demographic and clinical characteristics of the patients are shown in Table 1.

The mean duration of anastomoses performed on circumflex artery and left anterior descending artery was 8.3±1.5 min and 8.3±1.4 min, respectively (Table 2).

The number of distal anastomoses performed was more in the on-pump group than that of the off-pump group (*p*=0.036). A total of 124 coronary arteries in the off-pump group and 144 arteries in the on-pump group underwent anastomoses (Table 3). The consecutive grafting technique was not performed in any of our patients.

No mortality was observed in our series. However, low cardiac output syndrome necessitating intra-aortic balloon pump (IABP) occurred in two patients in the off-pump group and four patients in the on-pump group, despite inotropic support. In the on-pump group, two patients suffered from acute renal failure

Table 1
Demographic and clinical characteristics of the patients

	OP-CABG (n=52)		C-CABG (n=52)		<i>p</i>
	n	Mean±SD	n	Mean±SD	
Age (year)		59±11.3		54±11.7	0.13
Gender					0.26
Female	42		36		
Male	10		16		
Diabetes mellitus	12		18		0.27
Hypertension	22		28		0.29
Smoking	40		36		0.38
Peripheral arterial disease	8		10		0.50
Preoperative ejection fraction (%)		31.5±8.5		39.6±11.6	0.01
Obesity	6		8		0.50
Chronic renal failure	10		2		0.10
Cerebrovascular occlusion history	6		2		0.30
Family history	14		18		0.38
Hyperlipidemia	10		12		0.50
Preoperative history of MI	32		28		0.39
COPD	30		16		0.04
Unstable angina pectoris	6		10		0.35
Preoperative PTCA	8		10		0.50
Use of LIMA	40		38		0.50
Distal anastomoses		2.4±0.6		2.8±0.7	0.04

OP-CABG: Off-pump coronary artery bypass grafting; C-CABG: Conventional coronary artery bypass grafting; SD: Standard deviation; MI: Myocardial infarction; COPD: Chronic obstructive pulmonary disease; PTCA: Percutaneous transluminal coronary angioplasty; LIMA: Left internal mammary artery.

Table 2 Duration of anastomoses in off-pump group		
	Number of anastomoses	Duration of anastomoses (min)
	n	Mean±SD
Left anterior descending	52	8.3±1.4
Circumflex	52	8.3±1.5
Right coronary artery	12	8.1±1.4
Posterior descending artery	6	9.3±0.6
Diagonal	2	8.1±1.6
Total	124	8.4±1.5

SD: Standard deviation.

Table 3 Distribution of target coronary arteries		
Target vessels for anastomoses	OP-CABG	C-CABG
	n	n
Left anterior descending	52	52
Diagonal	2	8
Circumflex obtuse marginal 1	24	32
Circumflex obtuse marginal 2	28	28
Right coronary artery	12	12
Posterior descending artery	6	6
Total	124	144

OP-CABG: Off-pump coronary artery bypass grafting; C-CABG: Conventional coronary artery bypass grafting.

Table 4 Postoperative data					
	OP-CABG (n=52)		C-CABG (n=52)		p
	n	Mean±SD	n	Mean±SD	
Intraaortic balloon pump use	2		4		0.500
Postoperative acute renal failure	0		2		
Duration of intubation (hours)		10.6±2.3		16.1±3.9	<0.001
Respiratory failure	0		2		
Drainage (mL)		519±120		655±128	0.0002
Amount of transfusion (units)		0.9±0.7		1.9±0.7	<0.001
Perioperative myocardial infarction	0		2		
Necessity for postoperative inotropic support	8		18		0.100
Intensive care unit stay (days)		2.0±0.4		2.5±0.6	0.0010
Duration of hospitalization (days)		5.3±0.6		6.7±1.0	<0.001
Postoperative atrial fibrillation	6		12		0.233
Mortality	0		0		

OP-CABG: Off-pump coronary artery bypass grafting; C-CABG: Conventional coronary artery bypass grafting; SD: Standard deviation.

Table 5
Profile of patency of grafts in target vessels in off-pump and conventional groups

	Off-pump group						Conventional group					
	LIMA		SVG		Total		LIMA		SVG		Total	
	P	O	P	O	P	O	P	O	P	O	P	O
Left anterior descending	44	0	8	0	52	0	42	0	10	0	52	0
Diagonal	0	0	2	0	2	0	0	0	8	0	8	0
Circumflex obtuse marginal 1	0	0	24	0	24	0	0	0	32	0	32	0
Circumflex obtuse marginal 2	0	0	28	0	28	0	0	0	28	0	28	0
Right coronary artery	0	0	10	2	10	2	0	0	8	3	8	4
Posterior descending artery	0	0	4	2	4	2	0	0	6	1	6	0
Total	44	0	76	4	120	4	42	0	92	4	134	4

LIMA: Left internal mammary artery; SVG: saphenous vein graft; P: Patent; O: Obstructed.

(ARF), two patients from respiratory failure, and two patients from perioperative myocardial infarction. Such complications did not occur in the off-pump group (Table 4).

The mean duration of intubation was significantly shorter in the off-pump group (8.6±2.3 h) than the on-pump group (12.1±3.9 h) (p<0.001). The amount of drainage was 519±120 mL in the off-pump group, while it was 655±128 mL in the on-pump group (p<0.001). Similarly, the amount of transfusion was significantly lower in the off-pump group (0.9±0.7 U vs. 1.9±0.7 U, respectively). The mean preoperative EF was lower in the off-pump group, although there was a need for postoperative inotropic support more often in the on-pump group (n=18/8). The frequency of postoperative atrial fibrillation did not significantly differ between the groups (n=12 in the on-pump group and n=6 in the off-pump group). The mean length of ICU stay was shorter in the off-pump group (2.0±0.4 days vs. 2.5±0.6 days, respectively) (p=0.001). In addition, the mean hospitalization period was also shorter in the off-pump group (5.3±0.6 days vs. 6.7±1.0 days, respectively) (p<0.001) (Table 4).

Control coronary angiography results revealed that the arterial graft patency rates were 100% in both groups. The venous graft patency rates in the off-pump and on-pump groups were 95% and 95.8%, respectively. In both groups, the bypass grafts performed in the circumflex arteries were patent and obstructions invariably occurred in grafts where RCA anastomoses were made. The rates of patency of the grafts in the target vessels are plotted in Table 5.

DISCUSSION

Although CPB provides some advantages in coronary surgery, it stimulates coagulation and fibrinolysis as well as elicits activation of complement system, platelets and proinflammatory cytokines.^[3,4] In two distinct studies, stimulation of inflammatory pathways have been associated with increased morbidity and complications after coronary surgery and CPB.^[4] Due to hazardous outcomes of adverse reactions linked with CPB, advanced age of patients planned for surgery and accompanying COPD, alternative operations that do not include CPB have been preferred.^[5] Demonstration of safe anastomoses yielded an increase in OP-CABG. Publication of long-term angiographic results after OP-CABG have made this procedure popular worldwide. In our department, OP-CABG intervention has been performed since 2000 and about 20% of coronary bypass interventions have been carried out on beating heart.

We applied OP-CABG method to patients with LAD and RCA lesions and on posterior wall lesions in selected cases. The main challenge on revascularization of multiple vessels is maintenance of hemodynamic stability during access and exposure. These issues are more difficult to be accomplished on beating heart. In our series, we did not come across hemodynamic instability during revascularization of LAD. Deterioration of hemodynamics was noted on circumflex vessels located on posterior and inferior parts of heart, which constitute the most difficult regions for exposure. Experimental studies have shown that left ventricular functions were limited

and eventually hemodynamic instability was observed during anastomoses of circumflex arteries on beating heart.^[6] Decrease in cardiac index and increase in pulmonary artery wedge pressure were noted during revascularization of posterior wall. We kept our patients in Trendelenburg position to maintain hemodynamic stability in ectopia cordis position and pressure on right heart was relieved with this manoeuvre.

Even though CPB is termed as a risk factor for morbidity and mortality, prospective, randomized trials have shown that there was no difference between techniques with or without CPB in terms of morbidity and mortality.^[7] Revascularization on beating heart was not associated with increased mortality in early postoperative period.^[4] In contrast, decreased rates of morbidity and mortality were seen in some retrospective studies investigating OP-CABG.^[5,6] Incidences of perioperative mortality and perioperative myocardial infarction after OP-CABG were 1.9% and 2.9%, respectively.^[8] These results imply that OP-CABG is not associated with an increased likelihood of mortality than C-CABG. Our results are in accordance of this data.

Van Dijk et al.^[9] have compared OP-CABG and C-CABG in terms of surgical drainage and transfusion amounts. They reported that amounts of drainage in OP-CABG and C-CABG groups were 500 mL and 400 mL, respectively. The reason for the relatively increased amount of drainage in OP-CABG was attributed to the fact that heparin used during operation was not neutralized.

In conjunction with reports of Hoff et al.,^[10] we observed that amount of drainage was more in C-CABG. Routine use of anti-platelet factors, dilutional anaemia and direct effects of CPB may be responsible for this result.

Low cardiac output syndrome diagnosed postoperatively in both groups was managed successfully with IABP. Frequencies of IABP use in OP-CABG and C-CABG in our series were slightly higher than those reported by Ascione et al.^[11] Histopathological examinations demonstrated that mitochondria in the left ventricular cells were preserved better with OP-CABG.^[12] Moreover, manipulations for achieving access to the target vessels resulted in serious cardiac injury.^[13]

Cardiopulmonary bypass may contribute to the pathogenesis of ARF after CABG via hemodynamic,

inflammatory, and nephrotoxic effects. Hemolysis, decreased perfusion, non-pulsatile flow, and hemodilution may facilitate occurrence of ARF.^[14,15] Therefore, CPB has been postulated as an independent risk factor for ARF. From this point of view, OP-CABG may be an alternative for minimizing the risk of ARF. However, it should be kept in mind that low cardiac output syndrome which may occur during OP-CABG may enhance the pathogenesis of ARF. Therefore, appropriate preoperative hydration, avoidance of nephrotoxic drugs, the use of inotropic and vasodilator drugs for hemodynamic stability, and meticulous follow-up of acid-base balance are important measures for elimination of ARF.^[14,15]

Adverse effects of CPB on the respiratory system may become more obvious in COPD patients. In our series, no patients with COPD who underwent OP-CABG suffered from respiratory failure postoperatively. On the contrary, respiratory failure was detected in two patients with COPD operated via C-CABG. Bull et al.^[16] suggested that duration of extubation prolonged in C-CABG. Consistent with this finding, our results showed that duration of postoperative intubation were longer in the on-pump group. Shorter hospitalization accelerates the return of the patient to daily life and allows a more effective postoperative rehabilitation. In our series, the OP-CABG seems to be more favorable, since it is linked with a shorter duration of hospitalization.

Control of patency for anastomoses and grafts is an important parameter for documentation of the efficacy of OP-CABG. In the literature, the graft patency rates for C-CABG are reported between 94 to 99% in the early postoperative period and range between 51 to 98% in the long-term.^[17] Mechanical stabilization yielded a better graft patency in coronary vessels including the circumflex arteries.^[17,18] Compared to the OP-CABG and C-CABG, we found that the patency of the grafts was almost 100% similar to each other. At six months, the postoperative graft patency rate was 96.6% in the OP-CABG and 97% in the C-CABG. Endothelial injury due to intracoronary shunt was reported in the literature; however, we observed no stenosis or obstructions in anastomosis sites where the intracoronary shunts were used.^[19,20]

Our analysis of outcomes and preoperative and operative data of OP-CABG showed that postoperative

blood transfusion and drainage was less, and the length of intubation, hospitalization and ICU stay were shorter after OP-CABG. Graft patency rates were satisfactory in both groups and, remarkably, all anastomoses performed on the posterior vessels were found to be patent in the OP-CABG group.

In conclusion, in properly selected cases, targeted vessels on the posterior wall can be revascularized effectively and safely with OP-CABG.

Declaration of conflicting interests

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