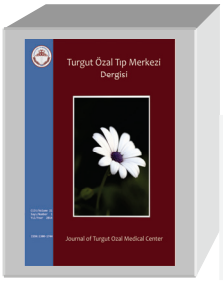

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Patient Selection Criteria For Off-Pump and On-Pump Coronary Artery Bypass Grafting

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Abstract

Background: This study compares safety, efficacy, and reasons of selection criteria between off-pump coronary bypass grafting (OPCAB) and conventional on-pump coronary bypass grafting (CCAB) in patients with coronary artery disease.

Material and Methods: The study feeds on a retrospective, observational cohort study of data collected from 540 consecutive patients with coronary artery disease undergoing isolated CABG (coronary artery bypass grafting) (270 OPCAB , 270 CCAB) between March 2003 and January 2013. Two hundred and seventy patients who underwent surgery with on-pump method (group 1) were compared to the group of 270 patients who underwent surgery with off-pump method (group 2).

Results: The mean number of anastomoses was 3.1±0.6 in group 1 and 2.1±0.7 in group 2; the difference was significant (p=0.016). The duration of mechanical ventilation support time was shorter for patients in group 2 (p=0.0001). The number of patients with three and/or four target vessel coronary artery bypasses in group 1 was substantially higher compared with the patients in group 2, while the number of patients undergoing one and/or two target vessel bypasses was substantially lower. The levels of CK-MB and troponin I were substantially lower in group 2. Group 2 patients demonstrated shorter hospital stay period than group 1 patients (p=0.0001).

Conclusion: The off-pump operation technique is preferred for patients with less target vessel anastomoses, while the on-pump operation technique is preferred for the patients with diabetes mellitus, multiple coronary artery lesions, and left main coronary artery (LMCA) lesions.

Key Words: Off-Pump Coronary Bypass; On-Pump Coronary Bypass; Myocardial Ischeamia.

Offpump ve Onpump Koroner Arter Bypass Greftleme için Hasta Seçim Kriterleri

Özet

Amaç: Bu çalışmada, koroner arter hastalıklarının tedavisinde off-pump ve on-pump cerrahi metodlarının, güvenilirliği, etkinliği ve teknik seçiminin nedenleri karşılaştırılmıştır.

Gereç ve Yöntemler: Mart 2003-Ocak 2013 tarihleri arasında izole KABG(Koroner Arter Baypas Greftleme) operasyonu uygulanan ardışık 540 hasta, retrospektif olarak karşılaştırıldı. On-pump metod ile tedavi edilen 270 hasta(Grup 1) ile off-pump metod ile tedavi edilen 270 hasta (Grup 2) karşılaştırıldı. On-pump metod (Grup 1) uygulanan hastaların, 215'i erkek ve 55'i kadındı ve ortalama yaş 56,3±9,3 idi. 27(%10) hastada sol ana koroner arter lezyonu tanısı kondu. Off-pump metod (Grup 2) uygulanan hastaların, 209'u erkek ve 61'i kadındı ve ortalama yaş 57,8±9,8 idi.

Bulgular: Koroner arter baypas yapılan damar sayısı grup 1'de 3,1±0,6; grup 2'de ise 2,1±0,7 idi. Bu farklılık anlamlı bulundu (p=0,016). Mekanik ventilatör desteğinde geçen süre grup 2'de daha kısa idi(p=0,0001). Grup 1'de üç ve/veya daha çok hedef damara baypas yapılan hasta sayısı, grup 2'ye göre daha fazla iken; bir ve/veya iki hedef damara baypas yapılan hasta sayısı ise, grup 2'ye göre grup 1'de daha azdı. CK-MB ve troponin I düzeyleri, grup 2'de daha düşüktü. Grup 2'deki hastaların grup 1'dekilere göre daha kısa hastanede kalış süreleri olduğu gözlendi (p=0,0001).

Sonuç: Off-pump operasyon tekniği, daha az sayıda hedef damar sayısı olan hastalarda tercih edilirken; On-pump operasyon tekniği ise diabetes mellitus(DM) tanılı, çoklu damar lezyonu olan ve sol ana koroner arter lezyonu tanısı olan hastalarda tercih edildi.

Anahtar Kelimeler: Off-Pump Koroner Baypas; On-Pump Koroner Bypass; Miyokardial İskemi.

INTRODUCTION

Vineberg implanted the internal thoracic artery directly into the myocardium with beating heart model in 1951. This beating heart technique was exchanged by cardiopulmonary bypass (CPB) in 1968 (1,2). The method was a revolution for the cardiothoracic surgery; however, cardiopulmonary bypass could also cause myocardial dysfunction. In time, the myocardial protection methods reduced the ischemic-reperfusion injury and systemic inflammatory response (3.4). Due to the complications of CPB, the off-pump technique was again popular among surgeons in the mid-1990s. The main objective was to avoid the adverse effects of potential extracorporeal circulation. Currently, 20 to 25% of coronary artery bypass procedures are performed in the USA with the off-pump method (5). As for our clinic, both methods are extensively used.

The purpose of this study is to discuss the selection criteria for the application and surgical techniques used

for patients undergoing CABG with the off-pump versus the conventional (on-pump) method.

MATERIAL AND METHODS

This study is a retrospective, observational, cohort study of data collected from patients with coronary artery disease. Two hundred seventy cases were performed with the off-pump (OPCAB) method between March 2003- January 2013 while exactly the amount of cases were performed using the on-pump method (CCAB). All surgeries were performed in our clinic by the same team. No exclusion criteria were implemented during the selection of the groups.

Group 1 consisted of 270 cases that enrolled CCAB (215 male and 55 female subjects with an average age of 56.3±9.3). 38 of the cases demonstrated chronic obstructive pulmonary disease (COPD), and 93 had diabetes(DM). The Euroscore was estimated to be 2.1±1.1, and 27 (10%) cases in CCAB group presented left main coronary artery (LMCA) lesions (Table 1).

Group 2 also consisted of 270 cases that underwent OPCAB (209 male and 61 female subjects with an average age of 57.8±9.8). 46 of the cases presented COPD, and 64 had DM. The Euroscore was estimated to be 2.2±1.2, and no patients displayed LMCA lesions (Table 1).

Table 1. Preoperative features of the patients. CCAB: Conventional Coronary Artery Bypass;

Variable	CCAB	OPCAB	P value
Number of cases (n)	270	270	1
Age (year)	56.3±9.3	57.8±9.8	0.98
Gender (F/M)	55/215	61/209	0.93
COPD (n)	38(14%)	46(17%)	0.0001
DM (n)	93(34%)	64(23.7%)	0.02
Unstable angina	64(23.5%)	75(27.7%)	0.84
Euroscore	2.1±1.1	2.2±1.2	0.98
Left Main Coronary Artery lesion (n)	27(10%)	-	0.0001

OPCAB: Off-Pump Coronary Artery Bypass; COPD: Chronic Obstructive Pulmonary Disease; DM: Diabetes Mellitus.

Anesthesia and surgical techniques were standardized for all patients. To induce anesthesia, 0.03mg/kg of midazolam, 0.3mg/kg of hypnomidate, 5µg/kg of fentanyl, and 0.1mg/kg of pancuronium bromide were applied. Maintenance of anesthesia was provided by 5µg/kg of fentanyl and 0.05mg/kg of pancuronium or vecuronium bromide.

In all cases, surgical access was gained via a median sternotomy. After harvesting the bypass grafts, heparin was administered (300 U/kg) before aortic cannulation. Anticoagulation was maintained during CPB and monitored with activated clotting time measurements (Hemochron 801, International Technique Corp, Edison, NJ, USA). Moderate systemic hypothermia (30 °C-32 °C) was induced in all the patients. A roller pump, a nonheparinized circuit, and a hollow-fiber oxygenator (Bentley, Univax Membrane Oxygenation Module, Baxter Healthcare Corp, Bentley Laboratory Division, Irvine, CA, USA) were used. The pump flow was maintained between 2.0-2.5 L/min/m^2 body surface area to ensure a consistent mean arterial pressure of 50 to 70 mmHg. Myocardial protection was achieved by an initial antegrade infusion of St. Thomas' crystalloid cardioplegia, followed by intermittent antegrade cold-blood cardioplegia.

When the LIMA-LAD anastomosis was accomplished in group 1, the dewarming process was performed. To avoid any reperfusion impairment and to provide a controlled reperfusion, hot blood was infused during the final step. Cross-clamp was then removed, and side clamp was carried out. The 100% occluded anastomosis was handled at last, and the proximal anastomoses were completed.

After median sternotomy and bypass graft harvesting, heparin (150 U/kg) was administered. The Octopus Tissue Stabilizer (Octopus- 3 28400, Medtronic, Cardiac Surgical Products, MI, USA) was used to stabilize the target coronary artery. First, the proximal anastomosis of the vein graft was constructed with the help of a partially occluder aortic-side clamp. In all cases, the left anterior descending (LAD) artery was the first coronary artery to be revascularized. The target coronary artery was stabilized and occluded proximally with a bulldog clamp, and the distal anastomosis was then performed. Heparin was antagonized with protamine sulfate until the activated clotting time dropped below 200 seconds.

Measured values are reported as means ± SD using the SPSS 16.0 statistical program. The normality of the distribution of the groups was juxtaposed with the Kolmogorov-Smirnov test, and non-parametric data were compared using the Chi-square test. Parametric data were appraised by independent the two-sample t-test. A p value <0.05 was considered as statistically significant.

RESULTS

Considering the demographic properties, the patients with COPD in group 2 substantially outnumbered those in group 1 (p=0.0001), whereas the number of patients with DM was substantially higher in group 1 (p=0.02). While group 1 included 27 patients with LMCA lesions, group 2 had none (p=0.0001) (Table 1).

The mean cross-clamp time (CCT) in group 1 was 48.3±3.9 min, and the total perfusion time (TPT) averaged 80.7±4.3 minutes. Since the off-pump group did not undergo the pump, these data were not analyzed statistically. The mean number of anastomoses was 3.1±0.6 in group 1 and 2.1±0.7 in group 2; the difference noted was significant (p=0.016). The mean drainage amount during the post-operative period was 447±158 ml in group 1 and 478±295 ml in group 2 (p=0.001). There was no difference between the two

groups regarding the total amount of blood used. Fresh frozen plasma (FFP) was used more frequently in group 1 (p=0.02). One case in group 1 and two cases in group 2 underwent intra-operative iatrogenic ascending aortic dissection, although no substantial differences were observed between the two groups. The length of time on mechanical ventilator support was 12.7±1.6 hours in group 1 and 6.4±1.2 hours in group 2 (p=0.0001). (Table 2).

Table 2. Peroperative features of the patients. CCT: Cross Clamp Time; CPB: CardioPulmonary Bypass; FFP: Fresh Frozen Plasma.

Variable	CCAB (n=270)	OPCAB (n=270)	P value
CCT (min)	48.3±3.9	-	-
CPB (min)	80.7±4.3	-	-
Mean number of total anastomoses	3.1±0.6	2.1±0.7	0.016
Drainage (ml)	447±158	478±295	0.001
Mechanical ventilation time (hour)	12.7±1.6	6.4±1.2	0.0001
Intra-operative aortic dissection (n)	1(0.5%)	2(1%)	0.87
Packed erythrocyte transfusion (ml)	600±50	560±50	0.81
FFP transfusion (ml)	560±50	520±60	0.02
Postoperative exploration(n)	5(2.5%)	6(3%)	0.91

Forty-one (25%) patients in group 2 underwent coronary bypass of a single coronary artery though no patients in group 1 underwent any bypass. Naturally, the number of patients undergoing bypass of a single coronary artery was substantially higher in group 2 (p=0.0001). Ninety patients (45%) in group 2 underwent bypass of two coronary arteries, as did 25 (12.5%) in group 1 (p=0.0001). The number of patients undergoing bypass of three coronary arteries was 121 (60.5%) in group 1 and 66 (33%) in group 2. The number of patients undergoing bypass of four coronary arteries was 48 (24%) in group 1 and 3 (1.5%) in group 2. The number of patients undergoing five or more anastomoses was 6 (3%) in group 1 and zero in group 2. The number of patients undergoing anastomoses of three and four coronary arteries was substantially higher in group 1, while there was no statistical difference between the groups in terms of the number of patients undergoing five or more anastomoses (Table 3).

Table 3. Operative results. CCAB: Conventional Coronary Artery Bypass; OPCAB: Off-Pump Coronary Artery Bypass.

Coronary Anastomoses(n)	CCAB (n=270)	OPCAB (n=270)	P values
One Vessel (n/%)	-	41(25%)	-
Two Vessel (n/%)	25(12.5%)	90(45%)	0.0001
Three Vessel (n/%)	121(60.5%)	66(33%)	0.0001
Four Vessel (n/%)	48(24%)	3(1.5%)	0.0001
Five Vessel (n/%)	6(3%)	-	-

Patients were analyzed for cardiac enzymes on postoperative day 1, 3, and 5. In group 1, the mean CK-MB value was estimated to be 51.3±13, and the mean troponin I value was 1.67±0.14. In group 2, these values were 46.3±15 and 0.21±0.12, respectively. The mean estimation for both values were substantially lower in group 2 (Table 4).

There were no substantial differences between the two groups regarding intra-aortic balloon pump (IABP) use, inotrope use, postoperative neurological complications, or mortality. Hospitalization of group 2 patients is shorter than that of group 1 patients (p=0.0001) (Table 4).

Table 4. Postoperative features of the patients. CCAB: Conventional Coronary Artery Bypass; OPCAB: Off-Pump Coronary Artery Bypass.

Variable	CCAB (n=270)	OPCAB (n=270)	P value
CK-MB	51.3±13	46.3±15	0.016
Troponin I	1.67±0.14	0.21±0.12	0.0001
Inotrope (n)	17 (8.5%)	15 (7.5%)	0.23
IABP	9 (3.3%)	6 (2.2%)	0.34
Neurological complications (n)	3 (1.5%)	7 (3.5%)	0.58
Mortality	3 (1.5%)	4 (2%)	0.65
Discharge period (day)	6.8±1.3	5±1,2	0.0001

With regard to the coronary anastomoses performed in both groups, circumflex and right coronary artery bypasses were more prevalent in group 1 than in group 2 (p=0.0001), while group 2 patients underwent substantially more diagonal artery and intermediary artery anastomoses compared to group 1 (p=0.001) (Table 5).

Table 5. Coronary target vessels of the patients. LAD: Left anterior descending artery; Cx-OM: Circumflex-Obtuse Marginal artery; RCA-PDA: Right Coronary Artery- Posterior Descending Artery

Variable	CCAB (n=270)	OPCAB (n=270)	P value
LAD	270	270	1
Diagonal-intermediary	129	147	0.001
$CxOM_1$-$CXOM_2$	264	82	0.0001
RCA-RCAPD	174	78	0.0001
Total	837	567	0.0001

DISCUSSION

OPCAB is reported to be a safe and effective technique due to the associated weak inflammatory response, low morbidity, early discharge from the hospital, and low costs (6). For the sustainability of the surgical method and the safety of the patient, it is important that the positions adjusted to the heart during circumflex (Cx) artery and right coronary posterior descending artery (PDA) anastomoses are tolerated (7). Consequently, the performance of several maneuvers during surgical operation is almost compulsory (8). In the present study, 131 (70%) of the patients undergoing the off-pump procedure had a single or double target vessel anastomoses. Therefore, especially for coronary artery anastomoses applied to the Cx artery, the on-pump method was initially preferred, and thus the patient was

protected from the abovementioned maneuvers and possible complications. The hospitalization periods for patients undergoing the off-pump procedure were also shorter than those experienced by the on-pump group.

The main benefits of the off-pump method are the reduction of the adverse effects on physiological systems of the CPB and the availability of accompanying body-cooling methods. This situation poses a substantial challenge to the limits of surgical indications. The off-pump method has been reported to be superior to operations performed using conventional CPB in cases of a low ejection fraction in older patients (70 and above), in cases of re-operation, in patient groups with cerebrovascular disorder, liver disease, bleeding dysfunction, and severe calcific aorta, or in patients for whom blood and blood products cannot be used (9,10) Although the limits of off-pump bypass surgery are frequently cited, based on the data obtained in the present study, CBP is safer with advanced CBP equipment, and it can be applied to elderly populations without any problems. The data obtained from patients exhibiting a low ejection fraction did not differ from those who underwent the off-pump technique. Even when off-pump was employed for severe calcific aorta, the hazardous risk did not vary as long as the clamping was placed on the aorta. For such patients, surgeons can overcome the issues by changing the grafting method (LIMA-RIMA and successive grafts, etc.) and cannulating the patient in other location (e.g., femoral artery). No differences were observed between the groups in terms of blood use. This might be due to the fact that we did not neutralize the heparin in a one-to-one manner in group 2. On the other hand, FFP was used more frequently in group 1.

In the off-pump procedure, the coronary artery is preferably maintained in the epicardium and it possesses a sufficient diameter value (>1.25 mm). Other desired criteria are that the lesion is not long and tortuos, and that endarterectomy is not required in the region where a possible anastomoses will be performed (11). It is quite difficult to provide these conditions, especially for diabetic patients. In the present study, 69 (34.5%) of the patients undergoing on-pump surgical operations had DM; this rate was substantially higher than that observed in the other group.

The immediate revascularization results for the beating heart after acute myocardial infarction were found to be relatively successful, and they suggested that CPB in patients, who are hemodynamically and electrically unstable, allows carrying out the operation on only the beating heart while also prevents global ischemia and yield more satisfactory results (11). In emergency revascularization, an off-pump bypass and bypass of the problematic vessel can be life-saving. However, due to the observed hemodynamic instability, the other problematic coronary artery should not be incorporated in the bypass. The other issue is that, for cases undergoing emergency revascularization, CPB application and carrying out a bypass on the beating heart are considered to be safe since cardioplegia is not involved.

The recent increase in prevalence of the off-pump technique raises the issue of safety. The technique is safe in cases with osteal or LMCA stenosis. In coronary surgery, detection of an osteal and LMCA stenosis is an indication for an operation, regardless of the clinical findings. The severity of the stenosis and the presence of clinical findings play a role in determining the duration of the operation. In a study comparing operations performed with the off-pump and the CPB (on-pump), Hirose emphasized that off-pump results for patients with main coronary lesions were reassuring (12,13). In the present study, in all LMCA lesions ⊠5%, on-pump surgery was found to be more appropriate in terms of patient safety. Attempts to apply the off-pump to patients with LMCA lesions, and then initiate a CPB when the hemodynamics deteriorates, may lead to undesired mortalities.

Chowdhury et al., in a prospective randomized study, analyzed the cardiac enzymes (heart-type fatty acid–binding protein, cardiac troponin I, high-sensitivity C-reactive protein, creatine kinase-MB) in patients who underwent the off-pump or on-pump technique. Levels of cardiac troponin I and heart-type fatty acid–binding protein were found to be more accurate than other enzymes in indicating postoperative myocardial injury (14,15,16). In our study, cardiac troponin I levels were sufficiently higher in group 1, as expected. Nevertheless, this value was lower than the abovementioned mean cut-off value. Moreover, considering that the number of bypasses applied was greater and that only anterograde cardioplegia was used, this value may represent an underestimation.

The off-pump technique is frequently preferred to other recently developed technologies; it is the first choice for patients who will undergo only a limited number of anterior wall cardiac diseases in our clinic. CCAB is avoided due to its associated undesired effects, long hospitalization period, and high cardiac enzyme values. On the other hand, the on-pump technique increases the quality of the anastomosis, particularly in patients with DM, small coronary artery diameter, and common lesions. Moreover, this technique should be indispensable for cardiac surgeons because it permits multiple bypasses of problematic regions, and it can be safely used for patients with LMCA and osteal lesions.

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