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Original Article

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Perioperative myocardial injury following off-pump and on-pump coronary bypass surgery: A prospective single-blind comparative study

Abstract

Aim: In our study, we aimed to demonstrate the relationship between myocardial damage and surgical technique in the perioperative period in patients who underwent off-pump and on-pump coronary artery bypass grafting (CABG).
Material and Methods: This prospective single-blind comparative study included a total of 49 patients undergoing on-pump CABG (Group 1, n=12), off-pump CABG (Group 2, n=30), and thoracotomy (Group 3 (as the study group), n=7). The groups were compared in terms of the preoperative basic clinical characteristics, intraoperative data, and postoperative outcomes and complications. In addition, the course of serum levels of creatine kinase (CK), creatine kinase-myocardial band (CK-MB), and Troponin Ic as biomarkers of myocardial injury was analyzed during the postoperative period.
Results: There were no significant differences between off-pump and on-pump CABG groups in terms of preoperative basic clinical characteristics, except for diabetes mellitus and significant left ventricular dysfunction. There were no significant differences between off-pump and on-pump CABG groups in terms of intraoperative data, except for number of distal bypass. Compared to off-pump CABG group, in on-pump CABG group the mean durations of extubation, ICU and hospital stay were significantly longer and the mean amounts of blood transfusion and hemorrhagic drainage were significantly higher. As the most spesific biomarker of myocardial injury in this study, Troponin Ic values were detected to be significantly higher in on-pump CABG group than in off-pump CABG group in blood samples taken at the times of postoperative 30th minute, and second, fourth and sixth hours.
Conclusion: We suggest that providing adequate myocardial stabilization, shortening the duration of coronary occlusion and thus avoiding major myocardial ischemia during off-pump CABG surgery are important points for achieving successful results with less myocardial injury.

Keywords: Myocardial injury, troponin, off-pump, on-pump, coronary bypass surgery

INTRODUCTION

Coronary artery bypass grafting (CABG) operations were initially performed on the beating heart, and later, they were routinely performed using a heart-lung machine after the development of extracorporeal circulation (ECC) techniques (1). The main purpose of using the ECC technique in CABG operations is to create a motionless and bloodless surgical field. Although excellent results have been achieved in CABG operations with ECC support in many cardiac surgery centers, there is still significant mortality and morbidity due to the adverse effects of ECC. In order to eliminate the adverse effects of ECC, CABG operations on the beating heart without ECC have been widely performed and gained increased popularity worldwide (2-4). This surgical technique provides the advantage of protecting against the adverse effects of ECC, but it has limiting factors such as the mobility of the heart, difficulty in reaching the lateral and posterior walls of the heart, and the bloody surgical field. These limiting factors have been eliminated with some methods such as the Octopus local myocardial stabilizer, the use of beta

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blocker agents, and pericardial suspension sutures. Thus, it has become possible to safely perform anastomosis to the coronary arteries on the lateral and posterior walls of the heart (5,6). There is limited information on perioperative myocardial cell injury and myocardial infarction rate in beating heart CABG. Non-invasive methods such as electrocardiography, echocardiography, myocardial specific enzymes, Creatine Kinase (CK), Creatine Kinase-MB (CKMB) and proteins (Troponin I, Troponin T) can be used as diagnostic methods in the determination of perioperative myocardial injury and infarction (7,8).

The aim of this study was to determine myocardial injury using noninvasive techniques in the perioperative period and to reveal the relationship between myocardial injury and operative technique in patients who underwent CABG on the beating heart without ECC or with ECC support.

MATERIAL AND METHODS

According to the national regulations and institutional guidelines in effect at the time of the study, ethical committee approval was not mandatory for retrospective studies.

Patients

Between October 1998 and March 1999, forty-two patients who underwent CABG (as the study groups) and seven patients who underwent thoracotomy (as the control group) in a tertiary referral hospital were enrolled to this prospective single-blind comparative study. Three groups for this were identified:

Group 1 (G1): Patients who underwent conventional on-pump CABG with ECC (n=12).

Group 2 (G2): Patients who underwent off-pump coronary artery bypass (OPCAB) on beating heart (n=30).

Group 3 (G3): Control group. Patients who underwent thoracotomy for any reason without ischemic heart disease (n=7).

Patients in G1 and G2 were randomly assigned to the groups using the closed envelope method.

Patients who underwent emergency, reoperative, concomitant surgery were excluded from the study.

Preoperative and Postoperative Examinations

All patients received routine examinations including hemogram, biochemical analysis including sodium, potassium, glucose, urea, creatinine, aspartate aminotransferase (AST) and alanine aminotransferase (ALT), telecardiography, electrocardiography (ECG) preoperatively and postoperatively at 24 hour intervals starting immediately after the surgical procedure. The patients' vital parameters as well as amounts of urine output and mediastinal an thoracic hemorrhage from tube drains were monitored continuously during the intensive care unit (ICU) follow-ups while regularly during the acute inpatient ward follow-ups. Complications (arrhythmia, infection, neurologic deficit, and other), extubation time, ICU and hospital discharge times were recorded. Serum CK, creatine kinase-myocardial band (CK-MB), and Troponin lc levels were measured in G1 and G2 at the times of preoperative (T0), postoperative 30th minute (T1), 2nd hour (T2), 4th hour (T3), 6th hour (T4), 12th hour (T5), 24th hour (T6), 2nd day (T7) and 3rd day (T8). In G3, serum CK and CK-MB levels were measured at the time intervals of T0, T2, T5, T6, T7 and T8 while serum Troponin lc levels were measured at the time intervals of T0, T2, T3, T4, T5, T6, T7 and T8.

Surgical Techniques

In G1 and G2 patients, following routine skin and subcutaneous incision and median stemotomy, the left internal thoracic artery (LITA) and simultaneously the great saphenous vein (SVF) were prepared as bypass grafts. Radial artery (RA) or right gastroepiploic artery (RGEA) was also prepared in minority of the cases. Pericardium was opened and then pericardial suspension sutures were placed. Unfractioned heparin was intravenously administered at the dose of 300 IU/kg for G1 and 100 IU/kg for G2 in order to achieve a target activated clotting time (ACT) ≥400 seconds for G1 and ≥300 seconds for G2.

In G1 patients, ascending aorta and right atrium were cannulated. Antegrade cardioplegia cannula was placed in the aortic root and retrograde cardioplegia cannula was placed in the coronary sinus. ECC was applied at 2.4-2.6 lt/m^2/min and mild hypothermia (rectal 30-32 C) was maintained. Mean perfusion pressure measured from the radial artery was maintained between 50 and 90 mm Hg. The aorta was cross-clamped and cardiac arrest was provided by administering blood cardioplegia with potassium at +4 C through the aortic root and topical cold serum was applied. Cardioplegic solution was given at 15-20 minute intervals. Distal anastomoses were performed with end-to-side or side-to-side anastomosis techniques using 7/0 polyprolene suture. After the last distal anastomosis was completed, warm blood cardioplegia was given retrogradely and then antegrade. Afterwards, the patients were warmed and the heart was started by releasing the aortic cross-clamp. Proximal anastomoses were performed with partial clamping of the ascending aorta. Heparin was completely (1/1) neutralized with protamine sulfate. After arterial and venous cannulas were removed, hemostasis was achieved and tube drains were placed, the chest was closed in the standard manner.

In G2 patients, Octopus was routinely used as myocardial stabilizer. In some cases where lateral and posterior wall stabilization of the heart was required, trandelenburg position, right rotation and deep pericardial suspension sutures were used to make the heart position suitable for visualization and anastomosis. Coronary arteriotomy was performed when local wall stabilization was achieved and hemodynamic status was stable. Proximal coronary occlusion was applied using microvascular bulldog clamps when coronary blood flow was too high to prevent visualization. Intermittent short-term air blower (filtered air <5 L/min) was used during anastomosis when necessary. ECG changes and ischemia durations were recorded during proximal coronary occlusion.

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Distal anastomoses were performed with end-to-side or side-to-side anastomosis techniques using 7/0 polyprolene suture. After distal anastomosis was completed, 75-100 cc 20% mannitol was intravenously administered. Proximal anastomoses were performed with partial clamping of the ascending aorta before or after distal anastomoses were completed. Heparin was partially (1/2) neutralized with protamine sulfate. After hemostasis was achieved and tube drains were placed, the chest was closed in the standard manner.

In G3 patients, lung resection, tracheal resection or decortication procedures through thoracotomy were performed.

Statistical Analysis

All statistical tests were performed using the Statistica® (Statsoft Inc) program. Anova-Manova multivariate analysis was used to evaluate biochemical measurements between the two groups and within-group repeated measurements. Categorical variables were compared using Chi square test while continues variables were compared using Student T-test or Mann-Whitney U test. Categorical variables were presented as number (percentage) continues variables were presented as mean±standard deviation unless otherwise stated. Values with $p<0.05$ were considered as statistically significant.

RESULTS

When the preoperative basic demographics of the patients who underwent on-pump CABG and OPCAB (G1 and G2) were compared, no significant differences were found between these two groups. When compared to the control group (G3), the patients in G1 and G2 were significantly older and had a male gender predominance. The frequency of diabetes mellitus was significantly higher in G1 than in the other groups. The frequency of significant left ventricular dysfunction was significantly higher in G2 than in the other groups. In terms of other preoperative basic demographics and comorbidities, there were no significant differences between the groups (Table 1).

When intraoperative data of patients in G1 and G2 were compared, the mean number of distal bypass in Group 1 was significantly greater. In terms of other intraoperative data, there were no significant differences between these two groups (Table 2).

When postoperative outcomes of the groups were compared, the mean durations of extubation, ICU and hospital stay were significantly longer in G1 than in G2. The mean amounts of blood transfusion and hemorrhagic drainage were significantly higher in G1 than in G2 and G3. In terms of postoperative complications, there were no significant differences between the groups (Table 3).

Table 1. Preoperative basic demographics and comorbidities of the groups

Variable	G1, on-pump CABG group (n=12)	G2, OPCAB group (n=30)	G3, thoracotomy group (n=7)
Age (year)	54.2±8.44	56.6±10.3	37.0±16.8
Gender (male/female)	8/4	23/7	2/5
Canadian angina classification	2.91±0.66	3.12±0.67	-
Diabetes mellitus	5 (41.6%)	3 (10%)	0 (0%)
Chronic obstructive pulmonary disease	2 (16.6%)	8 (26.6%)	0 (0%)
Significant left ventricular dysfunction	0 (0%)	7 (23.3%)	0 (0%)
Previous vascular surgery	0 (0%)	1 (3.3%)	0 (0%)
Previous cerebrovascular disease	0 (0%)	1 (3.3%)	0 (0%)
Anemia (hematocrit level <34%)	0 (0%)	2 (6.6%)	0 (0%)
Chronic renal failure	0 (0%)	0 (0%)	0 (0%)
Severe congestive heart failure	0 (0%)	4 (13.3%)	0 (0%)
Severe respiratory failure	0 (0%)	3 (10%)	0 (0%)

Table 2. Intraoperative data of the groups

Variable	G1, On-pump CABG group (n=12)	G2, OPCAB group (n=30)	G3, Thoracotomy group (n=7)
Complete revascularization	12 (100%)	30 (100%)	-
Number of distal bypass	3.5±1.1	2.5±0.9	-
X-clamp duration (min)	56±10.4	-	-
Arterial graft usage (per patient)	1±0	1.2±0.55	-
Left internal thoracic artery (LITA) usage	12 (100%)	29 (96.6%)	-
Radial artery (RA) usage	0 (0%)	4 (13.3%)	-
Right gastroepiploic artery (RGEA) usage	0 (0%)	2 (6.6%)	-
Inotrope requirement	0 (0%)	1 (3.3%)	-
Atrial fibrillation	0 (0%)	3 (10%)	-
Conversion to extracorporeal circulation (ECC)	-	0 (0%)	-
Endarterectomy requirement	0 (0%)	0 (0%)	-

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Table 3. Postoperative outcomes and complications of the groups

Variable	G1, On-pump CABG group (n=12)	G2, OPCAB group (n=30)	G3, Thoracotomy group (n=7)
Extubation time (hours)	8.3±5.5	4.2±2.2	-
Intensive care unit stay (hours)	44±13.5	18±5.1	-
Hospital stay (days)	6.4±2.5	4.2±1.2	-
Blood transfusion (unit/patient)	1.75±1.42	0.16±0.53	0.14±0.37
Hemorrhagic drainage (mL/in first 24 hours)	685±439	393±139	317±132
Low cardiac output syndrome	0 (0%)	0 (0%)	0 (0%)
Neurological deficit	0 (0%)	0 (0%)	0 (0%)
Atrial fibrillation	1 (8.3%)	3 (10%)	0 (0%)
Sternal dehiscence	0 (0%)	1 (3.3%)	0 (0%)
Wound infection	0 (0%)	1 (3.3%)	0 (0%)
In-hospital mortality	0 (0%)	0 (0%)	0 (0%)

Serum CK values were significantly higher in G1 than in G2 in blood samples taken at the times of T1, T2, T3 and T4. There were no significant differences in CK values in blood samples taken at other times between G1 and G2. When G1 and G2 were compared with G3 (control group), it was observed that CK values were significantly higher in G3 (control group) than in G1 and G2 at the times of T5, T6, T7 and T8 (Table 4, Figure 1).

Serum CK-MB values were significantly higher in G1 than in G2 in blood samples taken at the times of T1, T2 and T3. There were no significant differences in CK-MB values in blood samples taken at other times between G1 and G2. When G1 and G2 were compared with G3 (control group), it was observed that CK-MB values were significantly higher in G1 than in G2 and G3 at the time of T2 (Table 5, Figure 2).

Serum Troponin Ic values were significantly higher in G1 than in G2 in blood samples taken at the times of T1, T2, T3 and T4. There were no significant differences in Troponin Ic values in blood samples taken at other times between G1 and G2. When G1 and G2 were compared with G3 (control group), it was observed that Troponin Ic values were significantly higher in G1 than in G3 at the times of T2, T3 and T4 (Table 6, Figure 3).

Table 4. Mean pre- and postoperative CK values of the groups

	CK-T0	CK-T1	CK-T2	CK-T3	CK-T4	CK-T5	CK-T6	CK-T7	CK-T8
G1	58±17	447±184	631±198	717±244	756±309	760±264	768±347	680±412	499±288
G2	78±37	151±62	236±93	310±115	415±330	612±417	839±620	678±473	532±406
G3	79±57	-	553±162	-	-	1869±1294	1907±1187	2416±2637	1174±455
P value Gl-2	0.18	**0.0001**	**0.0001**	**0.0001**	0.01	0.37	0.76	0.99	0.83
P value Gl-3	0.58	-	**0.0002**	-	-	**0.003**	**0.008**	**0.009**	**0.008**
P value G2-3	0.99	-	**0.0002**	-	-	**0.0008**	**0.014**	**0.009**	**0.0012**

Table 5. Mean pre- and postoperative CK-MB values of the groups

	MB-T0	MB-Tl	MB-T2	MB-T3	MB-T4	MB-T5	MB-T6	MB-T7	MB-T8
G 1	6.4±6.9	59.4±30.1	63.4±25.8	68.3±32.7	60.7±33.7	46.4±23.0	35.6+ 19.4	21.0+ 11.7	20.8+ 12.2
G 2	6.7±6.1	16.7± 12.2	21.4± 16.5	19.2± 13.7	28.5±45.3	37.5± 52.5	44.7±46.7	28.3± 16.1	23.8± 17.8
G 3	8.0±3.2	-	18.5± 7.5	-	-	45.5±32.4	60.1± 57.3	108± 194	36.5+ 15.1
P value G l-2	0.98	**0.0001**	**0.0001**	**0.0001**	0.084	0.65	0.61	0.26	0.67
P value G l-3	0.86	-	**0.0002**	-	-	0.99	0.55	0.07	0.18
P value G 2-3	0.91	-	0.95	-	-	0.94	0.79	0.1	0.32

Table 6. Mean pre- and postoperative Troponin Ic values of the groups

	TR-TO	TR-Tl	TR-T2	TR-T3	TR-T4	TR-T5	TR-T6	TR-T7	TR-T8
G 1	0.1±0.0	17±6.5	34.6± 13.2	38.4± 11.0	33.7± 10.9	30.5± 15.5	18.9± 13.4	10.2± 12.1	5.5 ±6.8
G 2	0.62±1.8	2.6±4.0	5.9 ±7.15	7.3±7.8	9.3± 10.9	11.3± 14.1	10.3± 15.9	8.2 ± 14.4	5.8 ± 1 1.2
G 3	0.1±0.0	-	1.35±2.65	0.54±0.76	0.75± 1.11	1.2±2.3	0.65±0.89	0.57± 1.24	0.32±0.6
P value G l-2	0.43	**0.0001**	**0.0001**	**0.0001**	**0.0001**	0.003	0.17	0.72	0.92
P value G l-3	1.0	-	**0.0001**	**0.0001**	**0.0001**	0.0007	0.053	0.35	0.57
P value G 2-3	0.79	-	0.58	0.27	0.26	0.35	0.42	0.51	0.52

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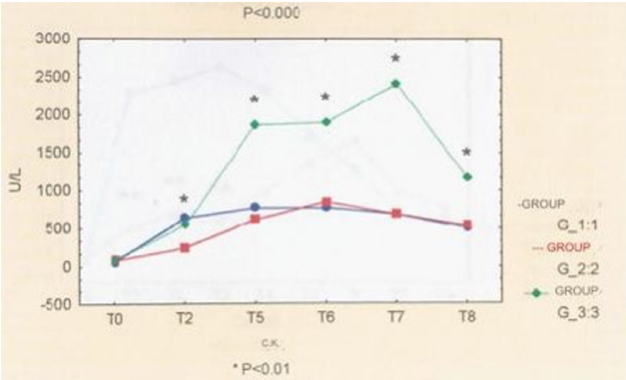

Figure 1. Mean CK activity values of Groups I, 2, and 3 patients varied between T0-T8 times

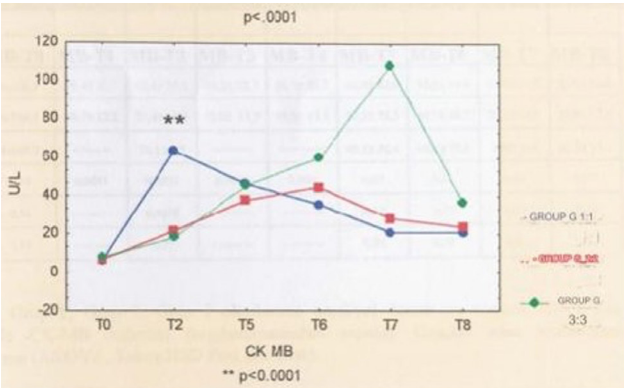

Figure 2. Mean CK MB enzyme activity values of Groups 1, 2, and 3 cases between T0-T8 periods

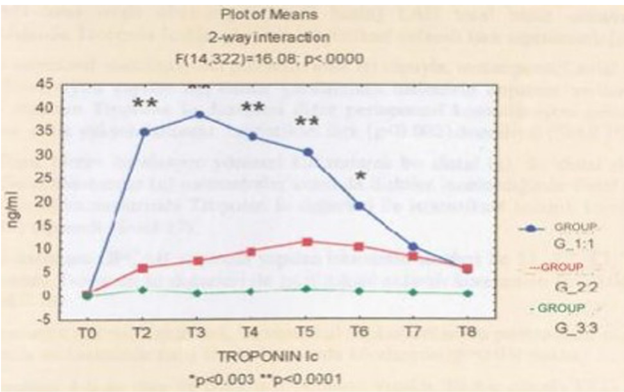

Figure 3. Mean Troponin I values of Groups 1, 2, and 3 between T0-T8

Subgroup Analyses Conducted Only in Patients who Underwent OPCAB Surgery

Troponin Ic levels were examined by dividing into two groups: performing proximal anastomoses of bypass grafts first (proximal a), and performing proximal anastomoses after all distal anastomoses were completed (proximal b). Although Troponin lc levels were generally lower in the proximal b group than in the proximal a group, no statistically significant differences were found between these two subgroups (Figure 4).

Troponin Ic levels were examined by grouping patients according to the number of distal anastomoses as one distal (a), two distal (b), three or more distal anastomoses (c). Although Troponin Ic levels in the distal a group were lower compared to the distal b and c groups, there were no statistically significant differences in the changes in Troponin lc measurements among these three subgroups (Figure 5).

Troponin lc levels were examined by dividing into two groups: anastomosis and occlusion times below 10 min/anastomosis (ischemia group a) and above 10 min/anastomosis (ischemia group b). Although Troponin lc levels of patients in the ischemia group were lower than those in the ischemia group b, the difference was not statistically significant (Figure 6).

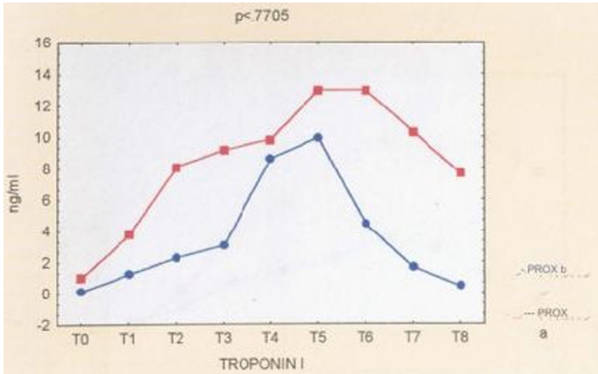

Figure 4. Changes in troponin l values between T0-T8 times in cases with proximal anastomosis before (proc a) and after (proc b)

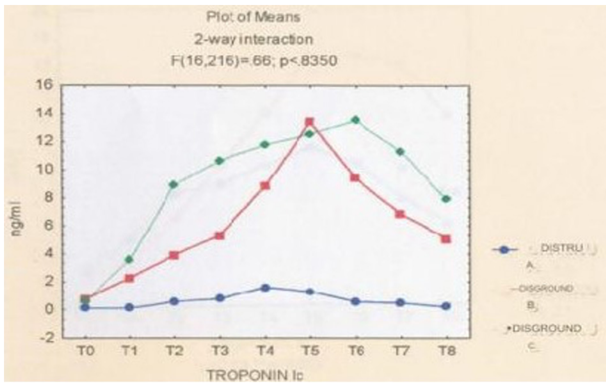

Figure 5. G2 cases Distal anastomosis groups (A, B, C) Troponin lc measurements mean values change between T0-T8 times

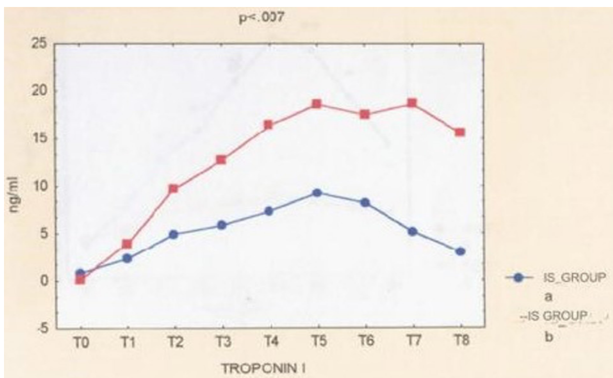

Figure 6. Anastomosis procedure durations below 10 minutes (a), and above (b) Mean troponin Ic measurement values change between T0 and T8

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DISCUSSION

CABG operations have been usually performed on the arrested heart using a heart-lung machine with ECC support. This conventional on-pump CABG method provides easiness to cardiac surgeons by creating a motionless and bloodless surgical field. However, this method also has some drawbacks such as hemodilution, systemic inflammatory response and subsequent end-organ injury, caused by ECC. These adverse effects of ECC can be avoided and the operation can be performed with lower risks by performing OPCAB on the beating heart (5,6). Thus, patients who are at high risk for CABG and are not initially considered for the surgery can be brought within the surgical limits with OPCAB method and the surgery can be recommended to these patients. Among the cases that underwent OPCAB in our study population, there were seven patients (three patients with severe respiratory failure and four patients with severe congestive heart failure) who were considered to be at high risk or beyond the risk limit for on-pump CABG surgery, and these patients were successfully operated with OPCAB technique.

With approximately 60 years of experience in coronary bypass surgery, certain standards have been established with very low risk and successful results. In order for coronary revascularization on the beating heart without ECC support to be considered successful, the standards obtained with the classical method must be reached. Clinical results such morbidity, mortality, graft patency, relief of angina must be similar or even better, complete revascularization must be possible, and the surgical procedure must be easy to perform on the beating heart with a reliable technique without causing dangerous hemodynamic deterioration and ischemic conditions. However, many cardiac surgeons are not accustomed to performing coronary anastomosis on the beating heart. Local mechanical stabilization of the myocardium has helped to spread the application of OPCAB surgery (3,9,10). In our patient group who underwent OPCAB surgery, complete revascularization was achieved with low morbidity and no mortality. Moreover, shorter durations of extubation, ICU and hospital stay were achieved and lower amounts of blood transfusion requirement and hemorrhagic drainage were observed in patients undergoing OPCAB compared to those undergoing on-pump.

It is difficult to recognize and clearly daignose perioperative myocardial injury following cardiac surgery. The electrocardiographic diagnosis of major myocardial injury is made by the presence of pathological Q waves and/or ST elevation. The occurrence of these ECG findings are reliable diagnostic criteria for perioperative myocardial infarction. In addition, the presence of newly developed regional myocardial movement disorder in echocardiographic evaluation is an important diagnostic indicator of perioperative myocardial injury or infarction (11,12). However, perioperative myocardial injury cannot be excluded even though the aforementioned findings are not present in ECG and echocardiographic evaluation. When myocardial injury occurs, serum levels of some cardiac enzymes and proteins increase with the release from myocardial cells (13). High CK-MB levels in serum are not completely specific for myocardial necrosis, but clinical diagnosis can be made by the characteristic increase in CK-MB in consecutive samples taken in the period following myocardial injury. Total CK and CK-MB activities exceed the threshold level within 4-6 hours after the development of acute myocardial infarction. The reason for this delay is the time required for ischemic damage, the solubility of intracellular CK, the passage of CK from the damaged sarcolemma to the lymph and its diffusion into the central circulation. CK activity peaks 10-20 hours after the development of infarction and returns to basal levels in 2-3 days. There is an increased risk and worse clinical outcomes as a result of an operation that involves destruction of a large area of myocardium. However, the increase in these enzyme levels is not sufficiently reliable in the detection of perioperative myocardial damage. High cardiac enzyme values frequently encountered in the postoperative period may also be related to factors such as surgical tissue trauma, cell destruction by ECC, myocardial dissection and blood transfusion (14,15). In this study, although no myocardial injury was detected in the control group, serum CK and CK-MB values were found to be higher in the control group than those in the on-pump CABG and OPCAB groups as of the 24th postoperative hour.

Troponins are regulatory proteins located within striated muscle. They regulate the interactions between actin and myosin. These proteins are present in low amounts in the cytoplasm and primarily form tight complexes of contractile structures. In healthy individuals, plasma levels are low. In the event of acute myocardial injury, the concentration of plasma Troponin I and Troponin T rises rapidly due to the release of cytoplasmic components, and they are released from the contractile structures for approximately a week due to cell fragmentation and death. Troponin Ic is known to be the most specific indicator of myocardial injury (12,13,16). While Troponin Ic is produced exclusively in the myocardium, CK-MB and Troponin T can also be produced in regenerating skeletal muscle (17,18). In patients in Group 1, Troponin I values were similar to those in Group 2 before the surgery, but the fact that they were significantly higher in later measurements, although not clinically significant, indicates that more ischemic myocardial injury occurred. Malik et al. (19) investigated myocardial injury following on-pump versus off-pump CABG by measuring heart-type fatty-acid–binding protein (hFABP) and CK-MB, and found that the total released amounts of hFABP and CK-MB were significantly higher in the on-pump than in the off-pump group. Similarly, Chowdhury et al. (20) investigated myocardial injury following on-pump versus off-pump CABG by measuring high-sensitivity C-reactive protein, cardiac troponin I, hFABP, CK-MB and myoglobin, and found that the total released amounts of hFABP, cardiac troponin I, and high-sensitivity C-reactive protein were significantly higher in the on-pump group than in the off-pump group. The results of our study were consisted with these studies. We similarly found that perioperative CK-MB and Troponin Ic values were significantly higher in the on-pump group than in the off-pump group.

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Although the relationship between perioperative myocardial injury and coronary occlusion times in OPCAB surgery has not been shown, the fact that the occlusion time per vessel did not exceed 15 minutes in our study population suggested that we did not reach the critical ischemia time. Although there was a difference in serum Troponin values between multivessel OPCAB and single or two-vessel OPCAB, the fact that it did not create statistical significance suggests that multivessel bypass does not cause serious ischemic injury in OPCAB surgery.

In some centers where OPCAB surgery is performed, several anatomical and clinical conditions such as the need for posterior wall revascularization (circumflex artery bypass), presences of low ejection fraction, dilated left ventricle and small-diameter coronary arteries are considered as negative selection criteria for OPCAB. On the other hand, although OPCAB surgery has a learning curve process, after this process is completed and sufficient experience is gained, OPCAB surgery on the beating-heart can be performed as the initial surgical revascularization strategy on every patient. However, it should be kept in mind that during OPCAB surgery there is a possibility/risk of conversion to on-pump surgery, albeit low (21-23). Considering the findings of our study, it was observed that OPCAB surgery caused significantly less myocardial injury compared to on-pump surgery. Moreover, in the comparison of OPCAB group with control group (G3, non-cardiac surgery group) in which no myocardial injury was expected, it was determined that the level of myocardial injury after off-pump surgery was not statistically significant.

There were also some important methodological limitations of our study. These important limitations were single-centered design, limited data analysis, inadequate sample size and imbalance between the groups.

CONCLUSION

OPCAB has been nowadays performed successfully and safely by many experienced cardiac surgeons. Providing adequate myocardial stabilization, shortening the duration of coronary occlusion and thus avoiding major myocardial ischemia during OPCAB surgery are important points for achieving successful results with less myocardial injury. We suggest that meticulous performance of the surgical technique, careful handling of the myocardium, and appropriate ordering and performing of anastomoses based on the experience are associated with the excellent results of OPCAB technique. However, further well-designed studies with larger patient participation are needed in order to support the findings of the present study and obtain more valuable scientific evidence.

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Patient Informed Consent: Informed consent was obtained from all patients for the use of their anonymized data in scientific research. Patient confidentiality and data privacy were preserved in accordance with the principles of the Declaration of Helsinki.

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