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Article

Comparison of On-Pump Beating Heart Surgery Versus Conventional Bypass Surgery in Patients with Acute Myocardial Infarction Requiring Urgent Revascularization

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Abstract

Background: The objective of our study was to provide the initial outcomes of the traditional coronary artery surgery approach and the on-pump beating heart surgery in terms of survival and morbidity in patients who needed emergency surgery for acute myocardial infarction. **Methods**: A single-center retrospective study was performed from November 2013 to September 2023 on a total of 212 patients requiring emergency coronary artery surgery. Group I patients (n = 108) received traditional coronary artery bypass grafting with cross-clamping, while Group II patients (n = 104) underwent on-pump coronary surgery on the beating heart. **Results**: There were no disparities observed in the preoperative left ventricular function, percutaneous coronary intervention, intra-aortic balloon usage, or clinical-hemodynamic characteristics. Group I patients had significantly higher rates of postoperative mortality and low cardiac output syndrome, as well as a greater utilization of intra-aortic balloons and a higher requirement for extracorporeal membrane oxygenation ($p < 0.001$). **Conclusions**: Ultimately, the on-pump beating heart approach could serve as a viable alternative to enhance the preservation of cardiac function and decrease postoperative complications and mortality rates in patients with acute myocardial infarction who require emergency surgery.

Keywords

on pump beating-heart; coronary artery bypass grafting; cardiac surgery; emergency myocardial revascularization

Introduction

Myocardial revascularization, also known as coronary artery disease interventions, refers to procedures that are commonly carried out to alleviate heart symptoms, prevent future ischemia episodes, and enhance survival in patients with coronary artery disease.

Some individuals may have surgical operations in addition to coronary interventional procedures involving stents or balloons. Conventional coronary artery bypass surgery (CABG) remains the predominant and standard procedure used globally for all patients who require surgical treatment for coronary artery disease. The procedure is commonly related to aortic cross-clamping, cardioplegic cardiac arrest, and cardiopulmonary bypass (CPB). Various mechanical and pharmacological approaches have been attempted in recent years to decrease the occurrence of intra- and post-operative complications associated with these operations.

The implementation of advanced myocardial protection techniques and complete re-vascularization operations has resulted in a decrease in the rates of morbidity and mortality that are linked to coronary artery bypass grafting (CABG). Nevertheless, the incidence of complications and death during surgery remains elevated in patients with acute myocardial infarction who require surgical intervention. Recently, beating heart coronary surgery methods have been employed for such patients in need [1–3].

In this study, a preliminary comparison was made between conventional and on-pump beating heart procedures in patients with acute myocardial infarction requiring urgent coronary surgical revascularization. On-pump beating heart coronary artery surgery was found to be superior to the conventional technique as a procedure allowing complete revascularization without causing hemodynamic instability in patients with myocardial infarction and persistent ischemic threat to the myocardium.

Material and Methods

This retrospective, single-center observational study included 212 consecutive patients who were diagnosed with an emergency surgical indication for acute myocardial infarction and underwent coronary bypass surgery between November 2013 and September 2023. The patients were chosen based on the indication for coronary bypass surgery due to an acute myocardial infarction. The patients were categorized into two groups based on the method used during myocardial revascularization. A total of 108 patients received traditional CABG (Group I), while 104 patients got CABG with a beating heart on pump (Group II) for the pur-

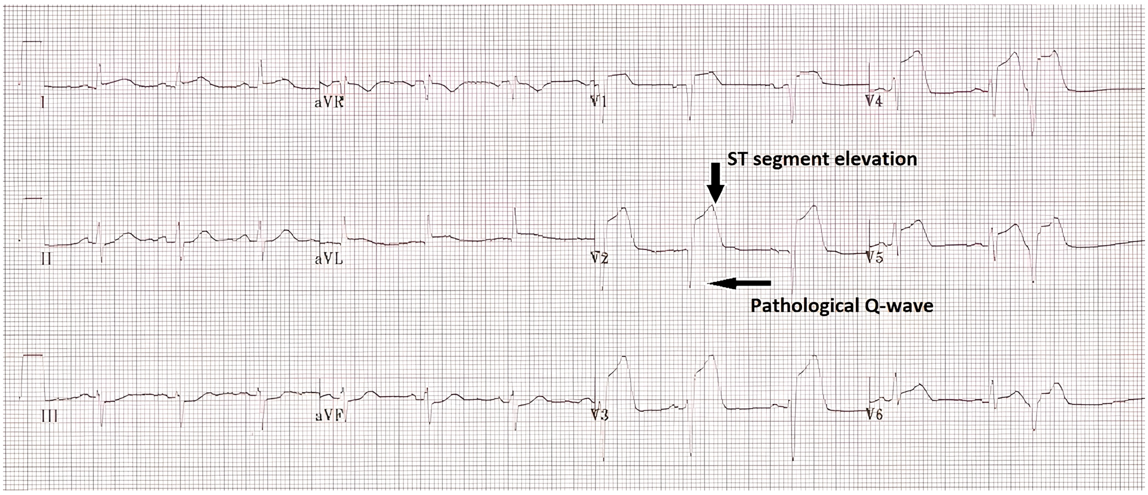

Fig. 1. 65 years old male with 2 hours duration of retrosternal chest pain. ECG shows ST segment elevations in antero-septal leads (V1–V6). ECG, Electrocardiography.

pose of myocardial revascularization. In Group I, the average age was 55.2 ± 2.7 years (ranging from 50 to 76 years), while in Group II, the average age was 59.4 ± 3.1 years (ranging from 51 to 75 years). All procedures were carried out by the same team, which was led by a single surgeon (Erkut B., MD). In addition to the preoperative preparation of the patients, the other surgeons also assisted in the maintenance and completion of the surgical procedures. The surgical procedures and techniques were chosen based on the practice of the initial surgeon.

The cardiology clinic assessed all patients who arrived at the emergency department with chest pain, supposing a preliminary diagnosis of myocardial infarction. When there were indications of myocardial infarction, such as persistent angina, abnormal changes in electrocardiogram results, and elevated troponin T levels seen in blood tests within a few hours, patients were transferred to the angiography unit (Fig. 1). Coronary revascularization was recommended for patients who had atherosclerotic lesions in their coronary arteries as detected by angiography, along with persistent myocardial ischemic threat and high troponin T values in blood tests. Initially, percutaneous interventional methods such as balloon angioplasty or stenting were attempted as an emergency measure (Fig. 2). Patients deemed ineligible for or unresponsive to these approaches were identified as potential candidates for urgent coronary artery surgery. The decision to perform emergency coronary artery bypass surgery for our patients was based on the 2011 ACCF/AHA criteria (Tables 1,2,3,4), which have evidence levels A–B and fall under Class I–II.

Definition and Follow-Up

Patients were closely monitored for any issues and parameters from the moment they were taken off CPB until they were discharged from the clinic following the surgery.

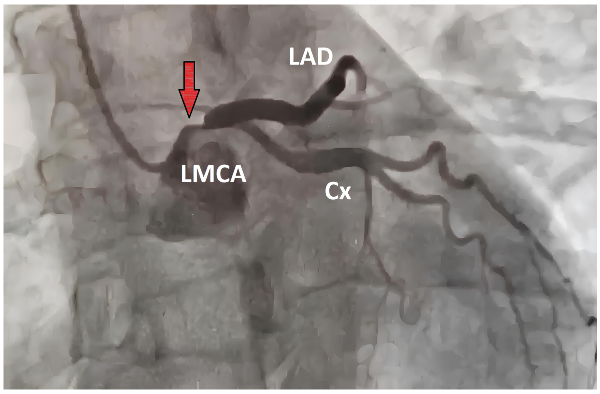

Fig. 2. This angiogram shows a catheter inserted into the left main coronary artery. The lesion in the artery is almost completely occluded (red arrow). LMCA, Left main coronary artery; LAD, Left anterior descending artery; Cx, Circumflex artery.

The study evaluated various factors, including patient mortality, requirement for inotropic support, utilization of an intra-aortic balloon pump (IABP), occurrence of low cardiac output syndrome (LCOS), necessity for extracorporeal membrane oxygenation (ECMO), administration of inotropic agents, renal failure, duration of stay in the intensive care unit and hospital, cardiac hemodynamic alterations, bleeding, rates of revision, infections, gastrointestinal, pulmonary, and neurological complications, and survival rates.

Hospital mortality was defined as the occurrence of death due to any cause within a period of 30 days following the surgical procedure. The mortality rates were categorized into two distinct time periods: early mortality, which refers to the first 48 hours, and late mortality. Due to the presence of two ECMO devices in our clinic, we did not assess the surgical death rate for our patients. Patients who were unable to be successfully removed off CPB at the conclusion of the surgery, either due to a low cardiac index

Table 1. Indications for emergency coronary artery bypass surgery.

-Percutaneous intervention, unsuccessful or not feasible, suitable anatomy for CABG, significant ischemia at rest, and/or hemodynamic instability refractory to medical treatment (3 conditions in combination)
-Recurrent angina or myocardial infarction within the first 48 hours after ST segment elevation myocardial infarction or heart attack with multi-vessel disease
-Over 75 years of age, ST segment elevation or left bundle branch block, suitable for revascularization, regardless of the time between myocardial infarction and cardiogenic shock; early revascularization with percutaneous intervention or CABG
-Patients in cardiogenic shock, in the presence of anatomy suitable for CABG; regardless of the time between myocardial infarction-cardiogenic shock or myocardial infarction-CABG
-Life-threatening arrhythmia thought to be of ischemic origin in patients with left main coronary stenosis of 50% or more and/or 3-vessel disease

Inspired by the 2011 ACCF/AHA CABC guidelines [4]; CABG, coronary artery bypass grafting.

or experiencing cardiac arrest during the weaning process, were thereafter linked to the ECMO device and sent to the intensive care unit (ICU).

If the cardiac index was below 2.2 L/min/per/m^2, patients were monitored and provided with pharmaco-mechanical support, such as IABP and/or ECMO. Postoperative renal impairment was characterized as a rise of 1.5 mg/dL in creatinine levels in comparison to the preoperative measurement. Neurological problems were characterized as either temporary or permanent neurological impairments occurring after surgery. The gastrointestinal consequences encompassed upper and lower gastrointestinal hemorrhages, intestinal ischemia, acute cholecystitis, and pancreatitis.

For Troponin-T measurement, 0.150 mL of heparinized venous blood was taken. The Cardiac T quantitative kit (Bio-medical Workshop, 2030 Wengjiao Haicang District, 361026 Ziamen, Fujian, China, https://www.wizbiotech.net/product-list/cardiac-test-kit) in the Cardiac Reader was used to measure the blood samples. The measurement was conducted using a sandwich immunoassay employing the gold labeling technique. The Troponin-T level should not exceed 2 ng/dL. The value of I should be below 0.03–0.06. The values may differ depending on the kits utilized by the laboratories and the institution. At our hospital, we analyze the Troponin-T value specifically for the detection of myocardial infarctions.

The cardiac index (CI) is the most commonly utilized metric for assessing cardiac performance. CI is a measure of cardiac output, expressed in liters per square meter per minute. The acceptable range for CI is from 2.5 L/min/m^2 to 4.0 L/min/m^2. The formula for cardiac index is CI = CO (cardiac output) $\times$ BSA (body surface area). In order to guarantee sufficient cardiac function following cardiac surgery, it is necessary for the CI to be higher than 2–2.2 L/min/m^2. A value below 2.0 L/min/m^2 strongly suggests the presence of cardiogenic shock.

Indications for preoperative IABP implantation include cardiogenic shock (with a cardiac index below 2.0 L/min/per/m^2), refractory ventricular failure, hemodynamic instability, refractory angina, ventricular arrhythmia, and significant left main stenosis (more than 70%).

The use of veno-arterial ECMO is specifically recommended for cases of severe cardiac dysfunction occurring in the operating room or intensive care unit following a surgical procedure, when there is the development of LCOS and persistent cardiogenic shock despite the use of inotropic agents and/or IABP. The circulatory system of the ECMO included an oxygenator made of polypropylene coated with heparin (Affinity, NT; Medtronic, Minneapolis, MN, USA) and a centrifugal pump (BPX-80 Bio-Pump, Medtronic, Minneapolis, MN, USA). The monitoring of blood flow was conducted using a Doppler flow probe that was linked to the arterial line of the ECMO. To prevent severe hemolysis, the maximum blood flow was restricted to 3.5 liters per minute. To mitigate the risk of hypothermia, a heat exchanger was linked to the oxygenator. The partial oxygen pressures of arterial and venous lines were observed. The arterial lines were kept at a minimum pressure of 300 mmHg, while the oxygen pressure in the venous lines was measured. All patients underwent femoral cannulation by connecting an 8-mm Hemashield prosthetic graft to the femoral artery using the cut-down technique. Our existing policy involved the use of ECMO in conjunction with IABP support to decrease the afterload.

Exclusion criteria: The study included patients who were hospitalized for acute myocardial infarction, had confirmed infarction through electrocardiography, clinical assessment, and blood tests, had angiographically determined coronary lesions, were not eligible for or unsuccessful in receiving interventional coronary artery intervention, and were urgently recommended and accepted surgical treatment. The study excluded patients who had previously undergone coronary revascularization or heart valve and combined cardiac surgery procedures, as well as those with post-infarction ventricular septal defect, left ventricular aneurysm, papillary muscle rupture, severe mitral regurgitation, and hypertrophic cardiomyopathy. In addition, this study excluded patients with hyperthyroidism, active infection, severe liver and kidney failure, inflammatory dis-

Table 2. **Preoperative data in patients undergoing emergency CABG.**

	Group I (n = 108)	Group II (n = 104)	*p* values
Sex (Male/Female)	61/47	58/46	0.112
Age (mean)	55.2 ± 2.7 (50–76)	59.4 ± 3.1 (51–75)	0.360
Hypertension	58	64	0.258
Smoker habits	91	94	0.501
Diabetes mellitus	68	77	0.710
Hypercholesterolemia	88	91	0.499
Creatinine level >1.6 mg/dL	9	10	0.460
Preoperative Troponin-T value (mean-peak, ng/mL)	759 (35–1345)	896 (41–1490)	0.211
CI	2.9 ± 1.7	2.7 ± 1.5	0.547
Angina not reduced by vasodilator therapy	95	90	0.655
Ventricular extra-systole	51	48	0.910
ECG (ST-elevation)	92	95	0.287
COPD	31	28	0.870
CVD	5	8	0.115
PVD	34	39	0.356
NYHA class (mean)	3.2 ± 1.04	3.4 ± 1.1	0.102
Preoperative inotropic intake	56	61	0.156
Preoperative vasodilator intake	42	39	0.896
Preoperative PTCA	54	48	0.642
Preoperative IABP	38	41	0.569
LVEF (mean %)	46.6 ± 2.5	47.7 ± 2.7	0.156
LVEDD (mm)	45.1 ± 3.1	44.2 ± 3.1	0.331
Triple vessel disease (angiographically)	81	79	0.977
Left main trunk stenosis >50% (angiographically)	77	68	0.451

ECG, Electrocardiography; CI, Cardiac Indexing; CVD, Cerebro-vascular disease; PVD, Peripheral vascular disease; NYHA, New York Heart Association; PTCA, Percutaneous transluminal coronary angioplasty; IABP, Intra-aortic balloon pulsation; LVEF, Left ventricle ejection fraction; LVEDD, Left ventricle end-diastolic diameter; COPD, Chronic obstructive pulmonary disease.

eases unrelated to coronary artery disease, previous myopathy, electrolyte imbalance, gastrointestinal disease, or pregnancy. Table 2 displays all preoperative data. Prior to commencing the trial, approval was sought from the Hospital Ethics Committee. Furthermore, all procedures were conducted in conformity with the principles outlined in the Declaration of Helsinki. Consent was obtained from the patient's relatives after providing them with all the necessary information.

Surgical Techniques: The procedures were conducted exclusively via a median sternotomy incision. The conduits (internal mammary artery and saphenous vein) were harvested and prepared. The initiation of CPB involved the insertion of a cannula into the ascending aorta and the use of two-stage venous cannulation in the right atrium. Both groups received heparin at a dosage of 300 international units per kilogram, aiming for an active clotting time greater than 450 seconds. Continuous flow was employed for CPB. Patients in Group I were subjected to severe hypothermia at a temperature of 32 degrees Celsius, along with intermittent ante-grade cold blood cardioplegia administered through the aortic root and saphenous vein grafts.

Traditional CABG: CPB was initiated by inserting a cannula into the aorta and draining blood from both the superior and inferior vena cava. The aorta was clamped and the myocard was protected using intermittent ante-grade blood cardioplegia (Del Nido cardioplegia). The cardioplegia solution consisted of Isolyte-S, mannitol (20%), magnesium sulfate (15%), sodium bicarbonate (8.4%, 1 mEq/L), potassium chloride (7.5%, 1 mEq/L), and lidocaine (2%). The distal anastomoses were conducted using either 7-0 or 8-0 polypropylene sutures, employing the continuous suture technique (Fig. 3). Following the removal of the cross clamp, the proximal anastomoses were joined to the ascending aorta using 5-0 or 6-0 polypropylene sutures with a side biting clamp into the aorta. Following the patient's removal from CPB and de-cannulation, the heparin was counteracted by administering a protamine infusion at a ratio of 1 to 1.5.

On pump beating-heart technique: The pump beating-heart procedure involved the preparation of the CPB circuit using identical methods and equipment as those used in traditional CABG. The procedure was carried out using normothermic beating heart support, without the use of cooling

Table 3. Operative data.

Variables	Group I (n = 108)	Group II (n = 104)	p values
CPB time (sec)	88 ± 26	90 ± 25	0.257
XCL time (sec)	26 ± 21	0	0.0001
Number of distal anastomosis	4.1 ± 0.5	4.0 ± 0.4	0.633
LAD by pass	108	104	0.788
Diagonal branches	72	69	0.108
Cx by pass	55	50	0.445
RCA by pass	49	54	0.396
Coronary endarterectomy	27	25	0.204
IMA usage	96	94	0.785
Cumulative regional ischemic times (min)	420 ± 110	450 ± 100	0.366
Arterial blood pressure (mmHg)	52 ± 20	108 ± 28	0.0001
Heart rate (min)	0 (cross clamping)	64 ± 11	0.0001
Left main disease	43	40	0.439
Three vessel disease	50	46	0.701
Two vessels disease	15	18	0.198
Complete revascularization	101	98	0.281
Conversion to conventional CABG	all conventional	4	0.005

CPB, Cardiopulmonary bypass; XCL, Aortic cross-clamping; LAD, Left anterior descending artery; Cx, Circumflex artery; RCA, right coronary artery; IMA, Internal mammarian artery (p values < 0.05; important statistically).

techniques. Regional myocardial immobilization was accomplished using a suction stabilizer, specifically the Octopus device from Medtronic in Minneapolis, Minnesota, and the Guidant Acrobat device from Guidant in Indianapolis, Indiana. The distal anastomoses were carried out initially, followed by the proximal anastomoses to the ascending aorta. Target vessel homeostasis was preserved during anastomoses through the temporary blockage of the proximal coronary artery and/or the utilization of a humidified carbon dioxide blower to enhance visualization (Fig. 4). Following the disconnection from CPB and removal of the cannula, the administration of heparin was counteracted by a protamine infusion.

Statistical Analysis

The group data were reported as the mean value plus or minus the standard deviation. The Mann-Whitney test was employed to analyze continuous variables, whereas Wilcoxon's signed rank test was used to compare pre and postoperative factors within the same group. The nonparametric variables were analyzed using Fisher's exact test. The Kaplan-Meier method was used to determine survival. Significant differences were seen in each analysis, with statistical significance determined using a p-value threshold of less than 0.05.

Results

The pre-operative data analysis conducted for both groups is displayed in Table 2. There were no disparities observed in the preoperative patients' characteristics between the two groups. Furthermore, there were no significant differences in the pre-operative usage of IABP, CI values or Troponin-T levels across the groups. The duration between the start of acute myocardial infarction and CABG was identical in both groups, with an average of 7 hours ± 3.7 and 9 hours ± 3.2, respectively.

The patients' intraoperative variables are presented in Table 3. The length of CPB was comparable in both groups. The average total number of distal anastomoses was 4.1 ± 0.5, compared to 4.0 ± 0.4 ($p > 0.05$). The groups did not differ in terms of the number of vessels bypassed, arterial conduit type, or surgical anastomosis sites. All patients had bypass surgeries using saphenous veins or internal mammary arteries (IMA) on the left anterior descending (LAD) arteries. However, in Group I, 12 patients and in Group II, 10 patients were unable to employ IMA due to inadequate blood flow or trauma-induced damage. Multiple stenosis necessitated the need for two anastomoses to the LAD artery in certain patients. There was no discernible disparity between the groups in relation to IMA usage. Full revascularization was not possible in 7 patients in Group

Table 4. Postoperative parameters between groups.

Variables	Group I (n = 108)	Group II (n = 104)	*p* values
Hospital mortality (within 30 days)	12	4	<0.05
Early (48 hours)	7	4	<0.05
Late (during postoperative term)	5	0	<0.05
New IABP insertion	31	6	<0.05
Duration of inotropic support (days)	6.7 ± 4.3	2.7 ± 3.1	<0.05
LCOS	48	11	<0.05
ECMO requirement	6	0	<0.05
Weaning from ECMO	1	2	>0.05
Postoperative renal dysfunction (Cr >1.5 mg/dL)	32	5	<0.05
Post-operative hemodialysis	9	0	<0.05
Pulmonary complications	14	12	>0.05
Neurological complications	8	2	>0.05
Gastrointestinal complications	4	1	>0.05
ICU stay (day)	9 ± 3	2 ± 2	<0.05
Hospital stay (day)	18 ± 4	6 ± 2	<0.05
Time to extubation (h)	41.2 ± 15	33.2 ± 14	>0.05
Infectious complications	9	5	>0.05
Surgical revision for bleeding	21	6	<0.05
Postoperative bleeding >1000 mL	29	9	<0.05
LVEF increase (>50 %)	28	21	>0.05
LVEDD decrease (<50 mm)	26	30	>0.05

AMI, Acute myocardial infarction; LCOS, Low cardiac output syndrome; IABP, intra-aortic balloon pump; ICU, Intensive care unit; LVEF, left ventricle ejection fraction; LVEDD, Left ventricle end-diastolic diameter; ECMO, extracorporeal membrane oxygenation.

I and 6 patients in Group II due to hemodynamic instability, unsuitable arterial diameter for anastomosis, or severe atherosclerotic lesions. Group I consisted of four patients who had conversion to conventional CABG as a result of refractory arrhythmia or hemodynamic worsening. Table 3 provides information on the prevalence of coronary artery disease in these patients.

An analysis was conducted on postoperative survival, complications, and data from Groups I and II (Table 4). The conventional CABG group included 31 patients who needed IABP insertion, while the on-pump cardiac method group had just six patients requiring this procedure. This disparity was found to be statistically significant ($p < 0.05$). The implantation of the IABP was necessary since all patients were unable to be successfully weaned from bypass due to LCOS. The prevalence of LCOS was greater in patients belonging to Group I. Furthermore, Group I patients exhibited a higher incidence of LCOS, resulting in increased utilization of IABP. Additionally, Group I patients showed a greater requirement for inotropic support and ECMO post-operatively, with both differences being statistically significant ($p < 0.05$).

The postoperative creatinine level, indicating renal impairment, was considerably lower in Group II compared to the preoperative value ($p < 0.05$), with a threshold of >1.5 mg/dL. Nine patients in Group I, who had increased creatinine levels after surgery, necessitated hemodialysis within a few hours. The difference between the groups was statistically significant.

The hospital mortality rate was 11.1% (12 patients) in Group I and 3.8% (4 patients) in Group II ($p < 0.05$). During the initial phase, a total of 7 patients from Group I and 4 patients from Group II who had IABP and ECMO treatment experienced fatalities. The obtained result is statistically significant, indicating that the cause of early mortality was the lack of response of LCOS to inotropic drugs, IABP, and ECMO assistance. Furthermore, the combination of continuous anticoagulant medication and renal insufficiency were additional risks contributing to mortality in certain individuals. Following the initial 48-hour period, mortality was observed exclusively among patients in Group I, with a total of 5 patients succumbing to death.

The echocardiographic evaluation conducted in both the intensive care unit and clinic during the first period did not show any significant statistical disparity between the groups in regards to the left ventricular ejection fraction and diameter ($p > 0.05$).

Furthermore, variations in the quantity of postoperative bleeding or drainage were seen among the groups. The postoperative bleeding volume exceeding 1000 mL was greater in Group I compared to Group II, and this difference was statistically significant ($p < 0.05$). Furthermore, Group

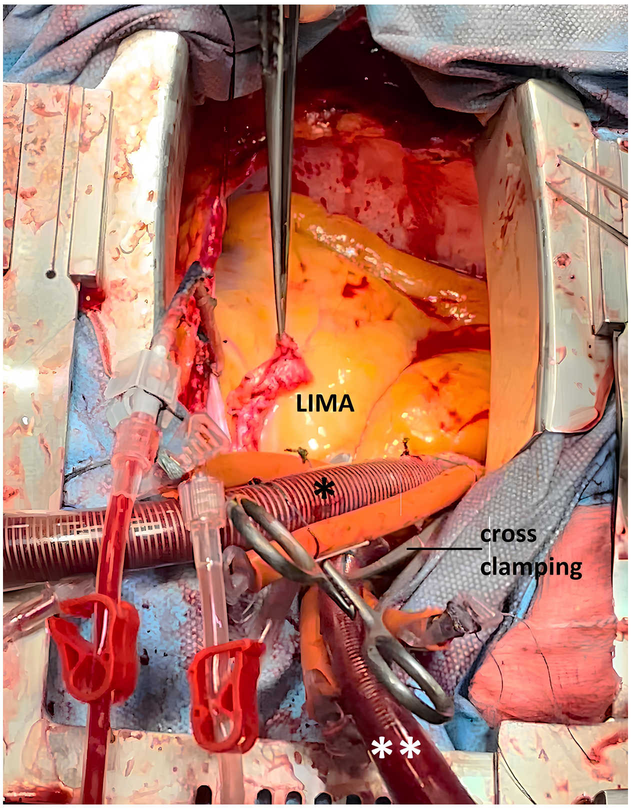

Fig. 3. Operative image of a patient who underwent emergency conventional coronary bypass surgery for acute myocardial infarction (LIMA-LAD bypass grafting), and CPB equipment (black asterisk: venous cannula; white asterisk; CPB, Cardiopulmonary bypass; LIMA, Left internal mammarian artery; LAD, Left anterior descending artery).

I exhibited a greater frequency of patients who required revision due to bleeding compared to Group II. These disparities were shown to be statistically significant. The escalation in bleeding quantity in Group I was linked to the extended period of CPB, the application of ECMO, and impaired renal function.

There was a significant disparity in ICU and hospital stays between the groups. In group II, the duration of ICU and hospitalization was much shorter compared to group I, with a statistically significant outcome ($p < 0.05$). In our study, we observed postoperative pulmonary, neurological, gastrointestinal, and infectious problems in both groups. However, the on-pump beating heart group had a decreased incidence of these complications.

Discussion

Postoperative complications and mortality remain significant concerns for individuals with acute myocardial infarction who need emergency coronary surgery. The surgical technique and myocardial preservation are crucial for these individuals. Although there have been advancements

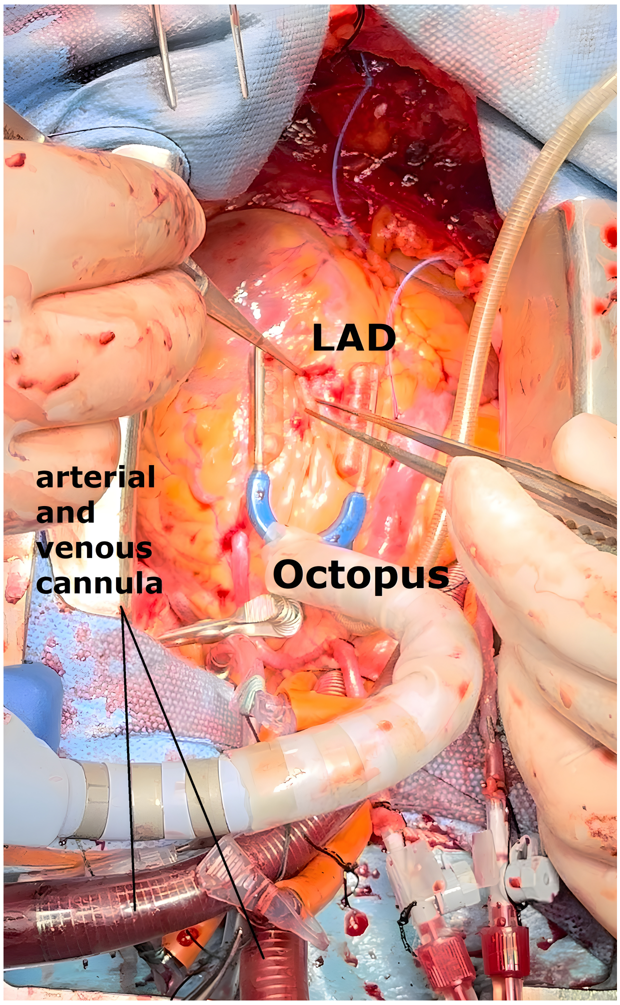

Fig. 4. Operative image in a patient undergoing on-pump beating heart coronary artery bypass surgery without cross clamping and cardioplegia (LAD anastomosis of the left internal mammary artery using Octopus stabilizer) (LAD, Left anterior descending artery).

in surgical procedures and their usage, the occurrence of post-operative complications caused by reduced blood supply during surgery has not been entirely eradicated [3–5]. Potentially, the condition could be addressed with the implementation of on-pump beating heart or off-pump CABG surgery.

Off-pump beating heart coronary surgery is a preferred procedure for patients who need immediate coronary bypass surgery due to myocardial infarction. Several studies have demonstrated that off-pump beating heart surgery yields comparable cardiac outcomes to traditional CABG procedures [6–9]. Although off-pump beating heart surgery has been proven to be effective and safe when compared to conventional CABG (which is associated with side effects of CPB, problems from cross clamp usage, and cardioplegia), some opponents argue that achieving full revascularization may be challenging in the majority of off-pump patients. Partial revascularization may not pose a major risk to patients right away, but it may cause recurrent angina, lower long-term survival chances, and necessitate further treatment in a few months or years [10–13].

Furthermore, a significant drawback of this method is the enduring occurrence of irregular heart rhythm and worsening in blood flow that may arise during the manipulation of the heart and necessitate immediate conversion to traditional cardiopulmonary bypass. During the perioperative period, if there is a need to switch to traditional on-pump CABG in emergency situations or when there are disruptions in the patient's blood flow or heart rhythm, it can result in a negative outlook and higher death rates during the hospital stay [12–17]. Consequently, a different method has been devised to maintain cardiac and hemodynamic stability, avoid the need for emergency conversion to traditional bypass, and achieve complete revascularization, all without the need for aortic cross-clamping under CPB guidance. This study aimed to assess the effectiveness of on-pump beating heart surgery in decreasing both mortality and morbidity.

A study shows that traditional CABG does not protect the heart that has had an infarction from ischemia as well as the heart that is beating. Several investigations have shown that troponin T levels are elevated in conventional CABG procedures compared to on-pump or off-pump beating heart surgeries [14–16]. In individuals experiencing infarction, it may not be possible to achieve sufficient cardiac output during the beating heart technique. Consequently, mechanical assistance from a CPB circuit, as part of a hybrid approach, is theoretically necessary. Several studies have demonstrated that the pump beating heart approach is associated with a decrease in creatine kinase-MB (CK-MB) release and myocardial injury when compared to standard CABG [17–19]. The early surgical outcome was superior in the on-pump beating group, which aligns with findings from other studies [18,19]. The levels of Troponin-T and CK-MB, which are likely indicators of damage to the heart muscle, showed lower increase in our Group I patients compared to the other group. This resulted in lower rates of LCOS, new IABP insertion (for weaning from CPB), the need for ECMO, and the duration of inotropic support during the postoperative period. The postoperative intensive care unit and hospital stays were reduced in the group that had the on-pump beating heart procedure. The conventional group experienced an extended discharge time from the intensive care unit and hospital due to prolonged hemorrhage, CPB support, and renal failure. Furthermore, the study revealed a notable decrease in the mortality rate among patients with acute myocardial infarction who received the on-pump beating heart procedure compared to the other group [1,3,19,20]. The mortality rates observed in our patients were mostly attributed to the extended CPB support necessitated by LCOS, bleeding, and renal damage. Group II exhibited a significantly decreased mortality rate in the first 30 days of hospitalization compared to the traditional group, with rates of 11.1% and 3.8% respectively. The primary distinction between the two procedures can be elucidated by the absence of cardioplegic arrest and the capability of CPB to achieve comprehensive revascularization. The findings were consistent with previous research [17,18]. The groups did not exhibit any notable disparities in terms of morbidity, including stroke incidence, gastrointestinal issues, pulmonary complications, bleeding volume, mediastinitis, and prolonged breathing. All of these are thought to be associated with the utilization of CPB.

Mizutani *et al.* [20] found that using the on-pump beating heart approach may heighten the likelihood of incomplete revascularization as a result of the reduced duration of the surgery and CPB time. Nevertheless, in concurrence with certain investigations, we ascertained that the on-pump beating heart approach exhibited a satisfactory quantity of grafts and achieved full revascularization [3,21,22]. The utilization of on-pump beating heart technology is a highly efficient approach to guaranteeing the ideal visibility of the coronary arteries. CPB serves to mitigate the occurrence of excessive filling and elongation of the heart. Consequently, the revascularization of the circumflex artery (Cx) and its branches can be readily accomplished by elevating the apex of the heart, ensuring stable hemodynamics and sufficient myocardial protection [12,13,19,21].

Renal failure frequently occurs as a complication in patients who are experiencing hemodynamic compromise or undergoing traditional CABG. Multiple studies have indicated that on-pump beating heart CABG provides superior renal protection. This is seen by a reduced likelihood of intraoperative systemic hypo-perfusion and a low occurrence of postoperative renal problems [3,23,24]. Given that the majority of patients experiencing acute myocardial infarction are experiencing unstable blood flow and inadequate perfusion of their internal organs, it is advisable to implement a suitable circulatory support system like CPB to enhance their blood flow and address the issue of organ perfusion [3,6,14,15,19–23]. Hence, the utilization of the on-pump beating heart technique presents a reduced likelihood of systemic hypo-perfusion during surgical procedures, resulting in enhanced renal safeguarding [3,23,24]. While we observed postoperative renal impairment in both groups in our study, the occurrence was notably reduced in the on-pump beating heart CABG group. Furthermore, the incidence of renal failure necessitating dialysis was greater in the traditional group, while no instances of renal failure requiring hemodialysis were seen in the on-pump beating heart technology group in our study. In addition, the systemic temperature of the individuals in Group II was roughly 36°C. The patients in the control group were subjected to a cooling process until their body temperature reached 30°C. The traditional group may experience more severe renal and visceral damage as a result of systemic cooling.

Many articles comparing on-pump and off-pump beating heart have been published over the years [2,25–29]. In some of these articles, patients with beating heart using a heart-lung machine (as in our article) were presented, while in others, beating heart cases without the use of a pump were presented and compared with the conventional bypass procedure. In all of these compared articles, beating heart cases were shown to be superior to conventional bypass in accordance with our series. In some series, more impressive results were obtained compared to our series because of the population of the region, angiography and number of cases, but the number of parameters compared in our series is higher than in many other studies [25–27]. In some of the presented patient series, only hematological and biochemical evaluation was compared, and in some others only postoperative complications were compared [26,28]. In some others, only postoperative mortality and morbidity rates were presented. In our series, in addition to many parameters in other articles, more valuable and meaningful data such as low flow rate and ECMO use were evaluated.

Cardiogenic shock following cardiac surgery is resistant to inotropic support, and the use of an IABP is uncommon but almost always results in death without mechanical circulatory support. It is commonly employed in numerous trials to treat poor blood flow or cardiogenic shock following any post-cardiotomy procedure [30–32]. ECMO was utilized in our patients with acute myocardial infarction following the surgical intervention. The utilization of ECMO was much greater in our patient cohorts who underwent traditional bypass surgery. Nevertheless, there was no discernible disparity across the groups in regards to the process of weaning from ECMO.

Study Limitations

There are several constraints associated with this study. To begin with, it lacks randomization. Nevertheless, it is possible to conduct accurate risk and outcome assessments and make comparisons by employing particular statistical evaluations. Furthermore, this study is a retrospective analysis conducted on a limited sample size of patients, hence restricting the reliability of the clinical findings. Additional research is required to better understand the advantages of enhancing myocardial revascularization in individuals using a heart pump. Furthermore, we assert that a larger sample size and extended duration of patient monitoring are necessary to ensure more robust statistical outcomes from this surgical method.

Conclusions

In this study, beating heart on pump technology was compared with the conventional technique to restore blood flow to the heart muscle in individuals requiring emergency coronary artery surgery following a heart attack. We propose on-pump beating heart cardiac surgery as the preferred option for myocardial revascularization in acute myocardial infarction, ventricular dysfunction, and ongoing ischemic conditions. By using the beating heart on pump approach, hemodynamic instability is avoided, and complete revascularization can be achieved without stopping the heart.

Availability of Data and Materials

The original data of this article can be requested from the corresponding author on reasonable grounds.

Author Contributions

Conceptualization: YK, BE. Data curation: IJ, ES, YK. Formal analysis: YK, BE, ES. Investigation: YK, BE. Methodology: YK, BE. Project administration: BE, ES, IJ. Resources: YK, BE, IJ. Supervision: YK, IJ, ES. Validation: YK, BE, ES. Visualization: IJ, ES. Writing–original draft: YK, BE. Writing–review & editing: YK, IJ, BE. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

Permission was obtained from the Erzurum City Hospital Ethics Committee before starting the study (The ethics approval number: 2024/022). In addition, all procedures were performed in accordance with the Declaration of Helsinki. Patients signed informed consent forms.

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Conflict of Interest

The authors declare no conflict of interest.

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