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Article

On Pump Beating Heart Coronary Artery Surgery in Patients Requiring Urgent Revascularization

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Abstract

Background: When acute coronary syndrome patients necessitate immediate revascularization, heart-on-pump coronary artery bypass grafting may be regarded as a viable substitute for conventional on-pump surgery. Our clinical experience and initial outcomes of heart-on-pump coronary surgery in patients with acute coronary syndrome are detailed in this article. **Method**: This research endeavor was a retrospective analysis that spanned the years March 2011 to August 2023. The sample size comprised 2816 patients who had undergone coronary artery surgery. During this period, the same surgical team performed coronary artery bypass surgery on 411 of these patients, who underwent beating heart surgery while on cardiopulmonary bypass support and without cardioplegic arrest; this was done under emergency conditions. **Result**: 9.3 $\pm$ 2.2 hours elapsed between the initiation of acute myocardial infarction and the commencement of coronary artery bypass grafting (CABG). A mean of 4.0 grafts was applied (2.2 $\pm$ 1.1). Mortality in hospitals was calculated for sixteen patients. Following surgery, twenty-six patients developed an inadequate cardiac output syndrome. Despite having renal dysfunction, none of the eight individuals needed hemodialysis. The mean duration of stay in intensive care was 3.2 (2.2 $\pm$ 1.1) days, while the mean length of hospitalization was 9.2 (4.3 $\pm$ 2.4) days. **Conclusion**: We believe that for high-risk patients with multivascular coronary artery disease who require an emergency coronary artery bypass graft, on-pump beating heart revascularization could be a viable option.

Keywords

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

Introduction

In cases of acute myocardial infarction, fibrinolytic therapy and/or percutaneous coronary interventions are the favored initial treatment options [1]. In certain circumstances, surgical intervention may be required to manage persistent unstable angina, non-ST segment elevation myocardial infarction, or ST segment elevation myocardial infarction. However, there are greater perioperative risks for patients with evolving acute coronary syndrome compared to elective cases undergoing early coronary artery bypass grafting (CABG) surgery. Elective cases have a 1.6% operative mortality rate, whereas arrested heart patients with conventional CABG may experience a 32% mortality rate; this disparity is highly dependent on the preoperative hemodynamic condition [2,3].

It is anticipated that patients in need of urgent surgical revascularization will experience the most significant advantages. However, patients with acute coronary syndrome, unstable angina, and severe cardiac failure are particularly vulnerable to emergency surgery. Numerous adverse events are induced by cardiopulmonary bypass (CPB) and cardioplegic arrest, which further increase the perioperative risk [4,5]. Hence, in an effort to mitigate the need for cardioplegic arrest, aortic cross-clamping, and CPB, the off-pump coronary artery bypass grafting (OPCAB) technique gained prominence during the 1990s. Its primary objective was to reduce mortality and morbidity among high-risk patients [6,7]. Regrettably, the OPCAB technique may induce transient episodes of hemodynamic instability during the extensive surgical manipulations and heart displacement maneuvers required to perform multiple distal anastomoses. These episodes may result in secondary, critical low coronary artery diastolic blood flow, which may subsequently progress to severe complications or mortality.

The term “on-pump beating heart technique” refers to a hybrid approach that combines conventional CABG and OPCAB. By diminishing the preload and afterload, this technique decreases the myocardial oxygen demand and maintains the beating heart’s ability to supply native coronary blood flow, which may mitigate myocardial damage. Previous studies have provided experimental evidence that sustaining cardiac contraction leads to reduced myocardial edema and a diminished inflammatory response [8]. We favored the on-pump beating heart technique for patients with acute coronary syndrome undergoing emergency surgery in light of these facts. In this study, we present our clinical experience and initial results regarding on-pump beating heart coronary surgery for patients diagnosed with acute coronary syndrome.

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Material-Methods

During the period spanning from March 2011 to August 2023, a total of 2816 patients had isolated CABG at our hospital. A cohort of 411 individuals received the on-pump beating heart operation without the use of cardioplegic arrest. The average age of the participants was 72 years, with a standard deviation of 4.1 years. The age range of the participants varied from 52 to 83 years old. A total of 151 patients (36.7%) underwent the insertion of an intra-aortic balloon pump (IABP). The preoperative indications for the installation of an IABP encompassed several criteria, including cardiogenic shock or refractory ventricular failure, hemodynamic instability, refractory angina, ventricular arrhythmia, and a severe left main stenosis above 70%. The guidelines include a comprehensive list of indications for emergency coronary surgery in all patients [9]. Fig. 1 (Fig. 1A,B) displays preoperative angiography pictures of two distinct patients who underwent emergency surgery. The surgical indications for patients who underwent emergency coronary bypass surgery are presented in Table 1 (Ref. [9]). During a 12-year period, all patients hospitalized for acute myocardial infarction who were angiographically unsuitable for an interventional coronary artery intervention, for whom surgery was indicated, and who accepted surgery were included. There were several additional exclusion criteria for this study. History of previous coronary revascularization or heart valve surgery, presence of left ventricular aneurysm, post-infarction ventricular septal defect, ruptured papillary muscle, severe mitral regurgitation, hypertrophic cardiomyopathy, hyperthyroidism, severe hepatic and renal insufficiency, inflammatory diseases other than coronary artery disease, active infection, electrolyte imbalance, patients with a heart rate less than 40 beats per minute, patients undergoing combined cardiac surgical procedures, and individuals with severe left ventricular diastolic dysfunction were excluded. Also, among our patients, in patients who developed refractory arrhythmia, hemodynamic disturbance and in whom we could not perform complete revascularization, we reverted to conventional bypass using cross clamping. These patients were not included in the study.

Participants were deemed ineligible for the study if they presented with severe liver illness or transaminase levels over 1.5 times the upper limit of normal, elevated serum creatinine levels of 2.5 mg/dL, a prior history of myopathy or elevated baseline creatinine kinase, past blood dyscrasia or gastrointestinal disease, or if they were pregnant. Table 2 presents the preoperative data. Permission was obtained from the Hospital Ethics Committee before starting the study. In addition, all procedures were performed in accordance with the Declaration of Helsinki. Informed consent was obtained from the patient's relatives.

Management of Intraoperative Anesthesia

General anesthesia was administered to all patients, ensuring that they maintained normothermia. Invasive hemodynamic monitoring commonly involves the routine placement of peripheral arterial and central venous catheters. The administration of intraoperative medications was carried out either through the peripheral pathway, which included induction and fluid infusion, or via a central venous catheter for maintenance purposes. The monitoring of core temperature was conducted using a bladder catheter. A five-lead electrocardiogram was frequently performed for myocardial ischemia and malignant arrhythmia. Transesophageal echocardiography (TEE) was used as needed to assess several cardiac conditions, including ventricular wall motion abnormalities, intra-cardiac thrombi, ventricular aneurysm, valve insufficiency, and volume status. The femoral artery was utilized as the location for catheterization in order to introduce an intra-aortic balloon pump. Additionally, patients who exhibited severe cardiac dysfunction or pulmonary arterial hypertension had a pulmonary arterial catheter inserted.

The average blood pressure (70 mmHg) and heart rate ratio were maintained at approximately 1.0 throughout the surgical procedure. A diminished cardiac output was deemed acceptable under the condition that the mixed venous oxygen saturation remained over 60% and there was no occurrence of metabolic acidosis. In instances of hypotension, various interventions were implemented, including elevating the legs, employing vasoconstrictors, administering increased fluid volumes, and ensuring the heart rate remained within the ideal range of 50 to 70 beats per minute. The surgical procedure was transitioned to on-pump, with the continuation of the specified settings for a duration exceeding 15 minutes, despite the implementation of intensive therapeutic measures. There are six criteria that can be used to measure the severity of a cardiac condition: (1) a cardiac index of less than 1.5 L/min/m^2, (2) a SvO_2 level below 60%, (3) a MAP below 50 mmHg, (4) ST segment elevation greater than 2 mV, (5) the presence of significant new wall motion abnormalities or a collapse in left ventricular function as determined by TEE, and (6) the occurrence of sustained malignant arrhythmias.

The criterion for the administration of allogeneic red blood cell transfusion was defined as a hemoglobin concentration of 9 g/dL or below or a hematocrit value of 27% or lower. The eligibility requirements for a fresh frozen plasma transfusion included a prothrombin time that was 1.5 times greater than the individual's baseline measurement, accompanied by the presence of widespread bleeding. The criteria for platelet transfusion entailed the manifestation of widespread bleeding and a platelet count below 50,000/mm^3, or the occurrence of platelet malfunction. At the conclusion of the surgical procedure, all patients received intraoperative cell salvage, which involved the autotransfusion of washed-recovered red blood cells.

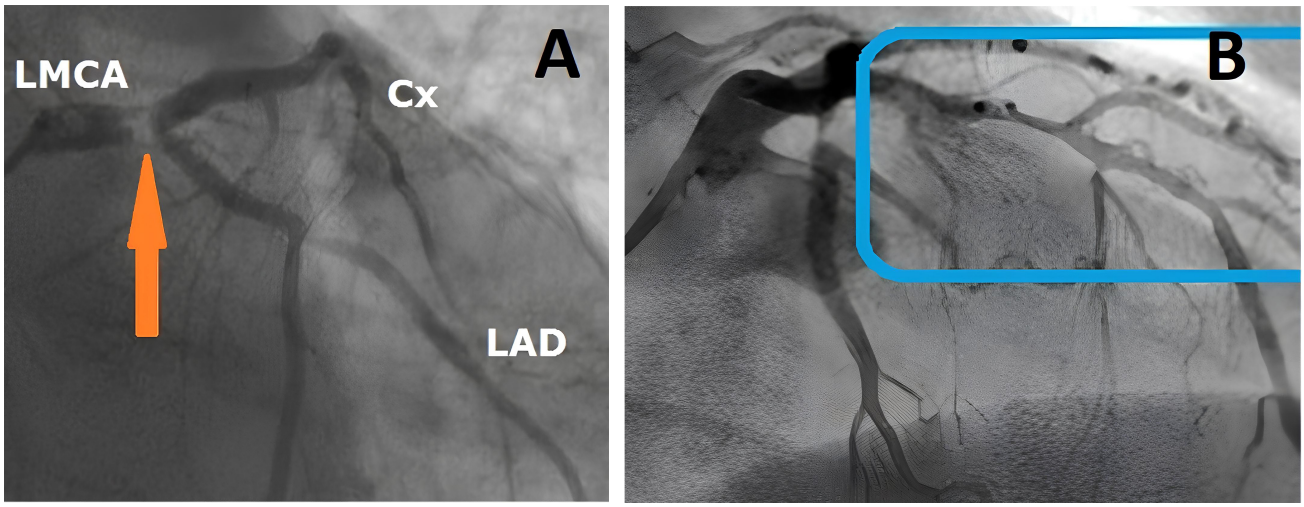

Fig. 1. Coronary angiography image in two separate patients with main coronary lesion (A) and widespread vascular disease (B) who urgently needed surgery. (A) Angiographic image in a patient with an LMCA lesion who underwent surgery for emergency revascularization (yellow arrow). (B) Coronary angiography shows a patient with diffuse atherosclerotic coronary artery disease in the LAD and persistent chest pain in addition to elevated troponin (blue frame). LAD, left anterior descending artery; Cx, circumflex artery; LMCA, left main coronary artery.

Table 1. Indications for emergency coronary artery bypass surgery.

Clinical and anatomical situation	Recommendation/level of evidence
Acute MI, inability or failure of primary PCI, anatomy suitable for CABC and persistent ischemia/hemodynamic instability over a large area	I/B
Cardiogenic shock, anatomy consistent with CABC, from onset of MI or shock regardless of the time elapsed	I/B
Left main coronary or triple-vessel disease in the presence of severe ventricular arrhythmia of ischemic origin	I/C
STEMI, multi-vessel disease, recurrent angina, CABC should be performed without delay in the first 48 hours of MI	IIa/B
STEMI/Left bundle branch block with shock in a patient over 75 years of age	IIa/B
Hemodynamically stable patient with persistent angina but viable myocardium confined to a small area	III/C
No-reflow state (epicardial reperfusion is present but microvascular reperfusion is insufficient)	III/C

Inspired by the 2011 ACCF/AHA CABC guidelines [9]; MI, Myocardial infarction; PCI, Percutaneous coronary intervention; CABC, Coronary artery bypass surgery; STEMI, ST-segment elevation myocardial infarction.

The management of intraoperative anesthesia involved the administration of a Diprivan® (Propofol, INN, AstraZeneca, Turkey) infusion at a dosage of 3 mg/kg in conjunction with Ultiva® (Remifentanil Hydrochloride, Pharmacy Retailing, Auckland, New Zealand) at a dosage range of 0.5–1 g/kg. Neuromuscular blockage was induced by administering Norcuron® (Vecuronium bromur, Merck Sharp & Dohme Pharmaceuticals Ltd., USA) at a dosage range of 0.1–0.15 mg/kg. Aramine® (Metaraminol Tartrate Injection, Phebra Pty Ltd., Australia) was administered to regulate the systemic pressure within the range of 50 to 60 mmHg. Additionally, Brevibloc® (Esmolol hydrochloride, Baxter, Turkey) at a dosage of 11 mg/kg was administered to reduce the heart rate as needed.

Surgical Technique

The heart was exposed through a median sternotomy. The conduits were collected and processed. CPB was established using an ascending aortic cannula and a two-stage venous cannula positioned in the right atrium. A dosage of 3000 IU/kg of heparin was administered in order to attain an active clotting time exceeding 450 seconds. A conventional circuit configuration was employed, comprising a tubing set, a roller pump, and a hollow fiber membrane oxygenator. The primary solution included 1000 mL of Hartmann solution, 500 mL of gelofucine, mannitol at a dosage of 0.5 g per kilogram, 7 mL of calcium gluconate at a concentration of 10%, and 60 mg of heparin.

The on-pump beating heart operations were regulated under mild hypothermia conditions using rectal temperature probes used to maintain a temperature range of 32–33 °C. The CPB circuit was comprised of a non-pulsatile flow rate of 2.4 liters per minute per square meter of body surface area. After inserting one to two traction sutures into the posterior pericardium, a mechanical stabilizer that was commercially available was employed. There was no intra-coronary shunt insertion. A prolene sling or bulldog

Table 2. Preoperative data.

Data	Number (411, n)	Percentage (%)
Sex (male/female)	224/187	
Age (mean ± SD, yr)	72 ± 4.1 years	
Hypertension	291	70.8
Smoker habits	379	92.2
Diabetes Mellitus	171	41.6
Hypercholesterolemia	299	72.8
Creatinine level >1.6 mg/dL	58	14.1
COPD	102	38.6
CVD	28	6.8
PVD	59	14.3
Arrhythmias	82	19.9
Atrial fibrillation	21	5.2
Premature ventricular beats	49	11.9
Ventricular tachycardia	12	2.8
Preoperative functional capacity		
NYHA I	78	18.9
NYHA II	151	36.8
NYHA III	144	35
NYHA IV	38	9.3
Preoperative PTCA	316	76.8
Preoperative IABP	151	36.7
Stable angina	91	22.1
Unstable angina	320	77.9
Triple vessel disease	378	91.9
Left main trunk stenosis >50%	258	62.7
LVEF (mean %)	37.4 ± 3.8	
LVEDD (mm)	52.2 ± 2.2	

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

clamp was utilized to apply antegrade blood control to the target vessel located in close proximity to the anastomotic site. The construction of the distal anastomoses preceded that of the proximal anastomoses. The initial revascularization procedure involved the left anterior descending (LAD) coronary artery, which was prioritized and treated using the internal mammarian artery (IMA). Subsequently, the circumflex (Cx) and right coronary arteries (RCAs) were revascularized. The use of a suction stabilizer device, specifically the Octopus, facilitated the regional immobilization of the myocardium. Additionally, a humidified carbon dioxide blower was employed to enhance vision (Fig. 2A,B). The distal anastomoses were performed using continuous sutures of 7-0 or 8-0 polypropylene. The proximal anastomoses were executed using 5-0 or 6-0 polypropylene sutures (Suture Ethicon Prolene, Johnson & Johnson, USA) while employing a partial occlusion clamp. Following the discontinuation of CPB and removal of the cannula, the administration of a protamine infusion (at a ratio of 1:1.5) was used to counteract the effects of heparin. Table 3 presents the intraoperative variables.

Definitions and Follow-Up

Hospital mortality was operationally defined as the occurrence of death, regardless of cause, within a period of 30 days following a surgical procedure. The definition of perioperative acute myocardial infarction encompasses the presence of new Q waves or a significant reduction in R-wave amplitudes, accompanied by peak levels of creatine phosphokinase fractions exceeding 10% of the total creatine phosphokinase. The condition known as low cardiac output syndrome (LCOS) was characterized by a cardiac index of less than 2.0 L/min/m^2, necessitating the use of pharmacological assistance and/or the insertion of an intra-aortic balloon pump (IABP). The criteria for postoperative renal dysfunction were established as an increase in creatinine values of 1 mg/dL or above in comparison to the preoperative baseline. Neurological problems were operationally defined as any temporary or permanent impairment of the nervous system that occurred after the surgical procedure. The gastrointestinal problems observed in this study encompassed several conditions, such as upper and lower gastrointestinal bleeding, intestinal ischemia, acute cholecystitis, and pancreatitis, as indicated in Table 4. All patients who survived underwent echocardiographic examinations at 1, 3, and 6 months postoperatively. The average duration of follow-up was 18 months, with a range of 2 to 24 months.

Results

Without cardioplegic arrest, the on-pump beating heart technique was utilized to perform emergency multiple myocardial revascularization on all 411 patients with acute coronary syndrome under the supervision of the same surgeon. Preoperative percutaneous transluminal coronary angioplasty (PTCA) was attempted on 316 patients (76.8%), but it was either ineffectual or could not be completed due to unstable hemodynamic conditions. The analysis of preoperative data is displayed in Table 2.

Between the initiation of AMI and the performance of CABG, 8.4 (5 ± 3.1) hours elapsed. 4.0 was the mean number of grafts (2.2 ± 1.1). 398 cases (96.8%) of LAD revascularization used the left IMA, whereas other coronary artery revascularization utilized the saphenous vein. In 92 cases (22.3%), coronary endarterectomy was performed exclusively on the side of the anastomosis. IMA grafts were harvested subsequent to the initiation of CPB. Thirteen IMA implants could not be harvested as a result of the patients' unstable hemodynamic status. All patients underwent revascularization of the LAD artery. In 388 patients

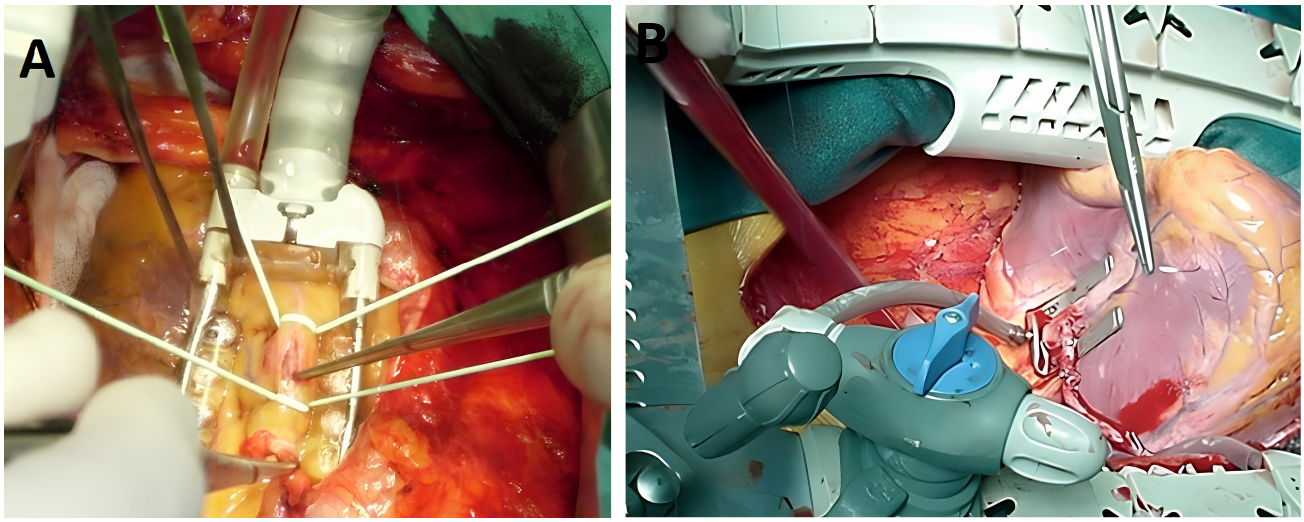

Fig. 2. Image of the IMA-LAD artery (A) and saphenous vein-Cx artery (B) anastomosis in our patient who underwent emergency surgery and on-pump coronary artery surgery on a beating heart using Octopus. IMA, left internal mammarian artery; LAD, left anterior descending artery; Cx, circumflex artery.

(94.4%), diagonal branches were grafted; in 201 patients (48.9%), Cx marginal 1 or 2 branches were grafted; and in 192 patients (46.7%), RCA was grafted.

Hospital mortality was 3.8% (16 patients); six patients perished in the operating room on the second postoperative day due to intractable ventricular fibrillation and global hypokinesia, and ten patients died on the same day due to ventricular fibrillation. Endarterectomy of the coronary artery was performed on 92 of these patients. Seven patients who underwent coronary endarterectomy developed perioperative myocardial infarction; both were managed with PTCA stent implantation of LAD or Cx.

Postoperative IABP was inserted in 42 patients who presented with intraoperative hypotension, global hypokinesia, and ventricular arrhythmia. The mean duration of the patient's stay with an IABP was 4.1 $\pm$ 0.7 (3.4 $\pm$ 0.9) days. Despite the occurrence of postoperative blood loss exceeding 1000 mL in 71 (17.2%) patients, surgical revision was required in 44 (10.7%) of these patients due to the denial of hemodynamic stability. 18 patients developed LCOS following surgery. Although six of them suffered from renal dysfunction, none required hemodialysis. The hospital length of stay was 9.2 (4.3 $\pm$ 2.4) days, while the average stay in the intensive care unit was 3.2 (2.2 $\pm$ 1.1) days. Eleven patients were identified as having postoperative neurological complications, seventeen as having pulmonary complications, and four as having gastrointestinal complications. All patients underwent transthoracic echocardiography prior to discharge; the average left ventricluar ejection fraction (LVEF) was 41.5 (45.4 $\pm$ 5.2) mm and the left ventricular end diastolic diameter (LVEDD) was 48.4 (41.5 $\pm$ 3.7) mm. Survivor follow-up lasted, on average, between two and twenty-four months. At 2, 18, and 24 months, the actuarial survival rate was 94%, 88%, and 81%, respectively.

Statistical Analysis

The statistical computations were conducted using SPSS (Statistical Package for the Social Sciences, version 17; SPSS Inc., Chicago, IL, USA) software on the Microsoft Windows platform. The data were statistically presented using measures such as the mean $\pm$ standard deviation for continuous variables. Additionally, frequencies (number of cases) or percentages were used when applicable.

Discussion

The objectives of myocardial revascularization encompass the preservation of existing myocardial function, the prevention of additional functional decline, and the activation of dormant myocardium to enhance ventricular functions [10]. In recent times, percutaneous catheter intervention procedures have gained significant popularity and are now widely regarded as the primary therapeutic option for acute myocardial infarction (AMI). Nevertheless, the existing criteria for emergency CABG surgery in patients with acute coronary syndrome are restricted to individuals who exhibit progressive myocardial ischemia that is unresponsive to the best available medical treatment, as well as those with left main stenosis and/or triple-vessel disease. Additionally, emergency CABG may be considered for patients who continue to experience ischemia despite either successful or unsuccessful PTCA, as well as those who have undergone complicated PTCA procedures [11].

With advancements in myocardial protection tactics, anesthetics, and surgical procedures, CABG has become a generally safe and effective procedure. However, it is important to note that despite these improvements, there are

Table 3. Operative data.

Variables	Number (n)	Percentage (%)
Hemodynamic data		
Arterial pressure (mean ± SD, mmHg)	66 ± 14 (59–110)	
Heart rate (mean ± SD, min)	55 ± 9 (40–77)	
CPB time (sec.)	64 ± 11	
Number of distal anastomosis (mean ± SD)	4.0 (2.2 ± 1.1)	
LAD bypass	411	100
Diagonal branches	388	94.4
Cx bypass	201	48.9
RCA bypass	192	46.7
Complete revascularization	392	95.3
Coronary endarterectomy	92	22.3
IMA usage	398	96.8
Conversion to cross clamp bypass surgery due to hemodynamic failure	0	0

CBP, Cardiopulmonary bypass; LAD, left anterior descending coronary artery; Cx, circumflex; RCA, right coronary arteries; IMA, left internal mammarian artery.

still instances of significant mortality and morbidity rates reported in emergency traditional CABG following acute myocardial infarction (AMI) [2,12,13]. This high prevalence can be attributed to the patient's poor preoperative condition, which encompasses factors such as cardiogenic shock, organ failure, and myocardial injury resulting from cardioplegic arrest. In the context of patients with AMI, the utilization of on-pump beating heart CABG may be considered a viable alternative to the traditional CABG procedure. This particular technique enables the continuous beating of the heart with the assistance of CPB without the need for aortic cross-clamping or cardioplegic arrest. The preservation of native coronary blood flow by the pounding heart has the potential to decrease myocardial damage [14]. Research findings have indicated that the preservation of cardiac rhythm leads to reduced myocardial edema and improved left ventricular performance. A further benefit associated with on-pump beating heart surgery is the ability to achieve excellent visibility of the coronary arteries [15]. This strategy mitigates the occurrence of excessive upward retraction of the heart, particularly in cases involving revascularization of the Cx branches [16,17]. Multiple studies on off-pump surgery have consistently shown favorable clinical results. The performance of OPCAB surgery appears to be a safe option for patients with acute coronary syndrome who are hemodynamically stable. In a retrospective analysis conducted by Locker *et al.* [18], a total of 77 individuals were included in the study. Among these patients, 40 underwent off-pump CABG, while the remaining 37 underwent conventional CABG. All patients included in the study had experienced a progressive acute coronary syndrome within a time frame of less than 48 hours. The utilization of off-pump CABG was found to be linked with a reduced rate of mortality during the patient's hospital stay ($p = 0.015$). However, it was observed that there was a greater rate of mortality in the latter period of 6 to 66 months ($p = 0.0066$). Additionally, a smaller number of distal anastomoses were conducted ($p = 0.0001$) [18]. In their study, Ben-Gal *et al.* [19] conducted two types of analyses, namely unmatched and propensity-matched, on a cohort of 1375 patients. The unmatched analysis included 221 patients who underwent off-pump CABG and 1154 patients who underwent conventional CABG. In the propensity-matched analysis, there were 220 patients who underwent off-pump CABG and 660 patients who underwent conventional CABG [19]. In the study, it was shown that propensity-matched off-pump CABG patients got a lower number of grafts compared to patients who underwent conventional CABG (2.8 [1.2] to 3.4 [1.03]; $p < 0.001$). However, no significant difference was found in terms of mortality within 30 days or at a later stage, as determined by both analysis methods. Moreover, while observing a decrease in non-Q wave myocardial infarction and bleeding incidents within 30 days, there was no discernible disparity in myocardial infarction, stroke, acute renal damage, or significant adverse cardiac events in either the immediate or prolonged periods when comparing off-pump coronary artery bypass grafting. The incidence of unplanned re-intervention was found to be significantly greater at the 30-day mark in patients who underwent off-pump CABG. However, no significant difference was identified in the occurrence of unplanned re-intervention between off-pump CABG and other procedures at the 1-year follow-up. The utilization of off-pump approaches for limited revascularization yields comparable long-term outcomes to full revascularization with CPB. However, this approach is associated with a threefold rise in re-interventions [20].

In this study, the cohort consisted of patients who exhibited unstable angina, poor ejection fraction, often three or more vascular illnesses, and necessitated frequent use of IABP support. The patients in question face limitations in terms of maintaining cardiac functions during revascular-

Table 4. Postoperative data.

Variables	Number (n)	Percentage (%)
Hospital mortality (within 30 days)	16	3.9
Operative mortality	6	1.5
Early mortality (within 48 hours)	10	2.4
Later deaths (after 2 months)	8	1.9
Perioperative MI	7	1.7
New IABP insertion	42	10.2
Duration of inotropic support (days)	4.1 $\pm$ 2.8	
LCOS	18	4.3
Postoperative renal dysfunction (Cr >1.5 mg/dL)	26	6.3
Postoperative hemodialysis	0	0
Pulmonary complications	26	6.3
Neurological complications	11	2.6
Gastrointestinal complications	6	1.4
ICU stay (day)	3.2 (2.2 $\pm$ 1.1)	
Hospital stay (day)	9.2 (4.3 $\pm$ 2.4)	
Infectious complications	21	5.1
Surgical revision for blood loss	44	10.7
Postoperative blood loss >1000 mL	71	17.2
Postoperative LVEF (mean %)	41.5 (45.4 $\pm$ 5.2)	
Postoperative LVEDD (mm)	48.4 (41.5 $\pm$ 3.7)	

IABP, Intra-aortic balloon pump; LCOS, low cardiac output syndrome; ICU, intensive care unit; LVEF, left ventricluar ejection fraction; LVEDD, left ventricular end diastolic diameter.

ization as well as achieving full revascularization. Hence, our preference is for the on-pump beating heart CABG technique, as it presents a potential surgical alternative for the most high-risk patients during the early post-infarctus phase. This paper presents an account of the initial outcomes observed in our clinic about the on-pump beating heart CABG technique. A cohort of 411 patients underwent emergency CABG for acute MI. Among these patients, 316 individuals (76.8%) presented with cardiogenic shock and received preoperative insertion of an IABP.

The use of the beating heart technique was generally completed without difficulty and with hemodynamic stabilization. During this technique, the coronary arteries were sometimes suspended proximally and/or distally from the anastomotic site with thick prolene sutures to prevent blood filling of the anastomotic area. Sometimes, a bloodless anastomosis area was created using small, thin, and sensitive bulldogs from the proximal and/or distal parts. When making these choices, the decision was made by looking at the anatomical structure of the coronary artery and the characteristics of the coronary lesion. This evaluation was made based on the experience of the surgical team, which has been using the beating heart technique for years and has performed many cases. The device called the octopus used during the application was provided by the hospital at a low cost. There was no difficulty in obtaining this device and its equipment. The devices and equipment that provided stabilization were not thrown away after being used on the patient. The devices could be used in approximately 25–30 patients after ethylene oxide sterilization. Therefore, it did not create a financial burden. Sometimes arrhythmia, tachycardia, and bradycardia attacks were corrected with medical treatment by experienced anesthesiologists. Despite these undesirable situations, especially during bypass procedures behind the heart (circumflex and/or obtuse arteries), none of our patients developed cardiac arrest during the procedure, and there was no need to proceed with the classical bypass procedure. Complete revascularization was achieved in most of the patients.

We tried to perform complete revascularization on all our patients, despite multiple coronary diseases. In general, in our study of high-risk patients, the use of a typical or conventional CABG procedure was considered excessively dangerous for patients. The use of on-pump beating heart technology has several benefits, including reduction of hemodynamic instability from surgical operations, prevention of global myocardial ischemia during aortic cross-clamping, and avoidance of reperfusion after cardioplegic arrest. A total of 26 patients (6.3%) had postoperative transient renal failure, while 33 patients (8%) were diagnosed with low cardiac output syndrome (LCOS). The in-hospital mortality rate was 3.9%. The observed levels of postoperative blood loss and the frequency of surgical revisions due to postoperative bleeding were higher than expected. This result may be attributed to the significant administration of heparin and antiplatelet drugs prior to the surgical procedure.

Based on the available evidence, it is our belief that the utilization of the on-pump beating heart revascularization procedure may present a favorable option for patients with multi-vessel coronary artery disease who are at high risk or require emergency CABG. Furthermore, it was observed that early revascularization leads to a reduction in the incidence of LCOS and its associated consequences.

Conclusion

We believe that on-pump beating heart revascularisation may be a viable option for high-risk patients with multivessel coronary artery disease requiring emergency coronary artery bypass grafting. We support the opinion that related studies should continue.

Availability of Data and Materials

Datasets used and/or analyzed for this study are available from the corresponding author upon appropriate request.

Author Contributions

(a) All authors have individually contributed to this study. YK and BE contributed significantly to the content/design of the study or to the collection of data for the study, ES and IJ contributed significantly to the analysis and interpretation. All authors take full responsibility for the study. (b) YK and BE drafted the manuscript and critically reviewed important intellectual content. (c) All authors have seen the final version of the submitted manuscript and have reviewed and approved it. (d) They have agreed to take responsibility for all aspects of the work to ensure that questions concerning the validity and accuracy of any part of the work have been properly investigated and resolved.

Ethics Approval and Consent to Participate

Permission was obtained from the Hospital Ethics Committee (Atatürk University) before starting the study. In addition, all procedures were performed in accordance with the Declaration of Helsinki. The ethics approval number of our manuscript is 6722/32. Patients signed informed consent forms.

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Conflict of Interest

The authors declare no conflict of interest.

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