original article

On-pump beating heart coronary revascularization: Is it valid for emergency revascularization?

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BACKGROUND: On-pump beating heart coronary artery bypass grafting (CABG) may be considered as an alternative to the conventional on-pump surgery in patients presenting with acute coronary syndrome requiring emergency revascularization. This study reports our clinical experience and early outcomes with the on-pump beating heart coronary surgery on patients with acute coronary syndrome.

DESIGN AND SETTINGS: A retrospective study conducted from August 2009 to October, 2015, in a regional training and research hospital in Turkey.

METHODS: A total of 1432 patients underwent isolated CABG at our institution. A total of 316 of these patients underwent the on-pump beating heart procedure without cardioplegic arrest by the same surgeon.

RESULTS: The time interval from the onset of acute myocardial infarction to CABG was 10 (2.2) hours. The mean number of grafts was 3.0 (0.6). Hospital mortality was 2.9% (9 patients). Twelve patients had low cardiac output syndromes after surgery. Eight of them had renal dysfunction but none of them needed hemodialysis. The mean intensive care unit stay was 3 (2) days and the mean hospital length of stay was 7 (4) days.

CONCLUSION: We think that the on-pump beating heart revascularization technique can be a good choice for emergency CABG of high-risk patients with a multivessel coronary artery disease.

Fibrinolytic therapy and/or percutaneous coronary interventions are the preferred first-line therapeutic modalities for acute myocardial infarction (AMI).[1] Surgical treatment is sometimes inevitable in cases with continuing unstable angina, non-ST segment elevation MI, and ST segment elevation MI. But patients with evolving acute coronary syndrome have higher perioperative risks compared with elective cases when early coronary artery bypass grafting (CABG) surgery is performed. With conventional CABG on arrested heart, operative mortality can be as high as 32% compared with 1.6% in elective cases, and this difference strongly depends on the preoperative hemodynamic condition.[2,3]

Patients requiring emergency surgical revascularization are expected to derive the greatest benefits. But especially these acute coronary syndrome patients with unstable angina and severe cardiac failure are extremely sensitive to emergency surgery. The use of cardiopulmonary bypass (CPB) and cardioplegic arrest trigger many undesired events contributing to high perioperative risk.[4,5] Therefore, to avoid the use of CPB, aortic cross-clamping and cardioplegic arrest, the off-pump coronary artery bypass grafting (OPCAB) technique was popularized in the 1990s with the specific purpose of reducing the mortality and the morbidity in high-risk patients.[6,7] Unfortunately, during the extensive surgical manipulations and heart displacement maneuvers necessary to perform multiple distal anastomoses, the OPCAB technique can cause episodes of transient hemodynamic instability leading to secondary critical low coronary artery diastolic blood flow followed by severe complications or death.

The on-pump beating heart technique can be defined as a combination of OPCAB and conventional CABG. Using this technique, myocardial oxygen demand is

reduced by reducing the preload and afterload and the beating heart can preserve native coronary blood flow, which might reduce myocardial injury. Experimentally, it has been demonstrated that maintaining the heart beating results in minimal myocardial edema and less inflammatory response.[8] Based on these facts, we preferred the on-pump beating heart technique on patients with acute coronary syndrome undergoing emergency surgery. In this study, we report our clinical experience and early outcomes with the on-pump beating heart coronary surgery on patients with acute coronary syndrome.

METHODS

Between August 2009 and October 2015, 1432 patients underwent isolated CABG at our institution. A total of 316 of these patients underwent the on-pump beating heart procedure without cardioplegic arrest. The mean age was 68 (4.8) years (Min: 55, Max: 77 years). The mean left ventricular ejection fraction (LVEF) was measured as 27.7 (4.7%) and the left ventricular end-diastolic diameter (LVEDD) was 64 (3.2) mm. An intra-aortic balloon pump (IABP) was inserted in 185 patients (51.3%). The criteria for preoperative insertion of an IABP were as follows: cardiogenic shock or refractory ventricular failure, hemodynamic instability, refractory angina, ventricular arrhythmia, and a critical left main stenosis (>70 %). Patients with LV aneurysm, post-infarction ventricular septal defect, ruptured papillary muscle, severe mitral regurgitation, and combined surgical procedures were not included in the study. All preoperative data are depicted in **Table 1**.

Management of Intraoperative Anesthesia: Anesthesia consisted of propofol infusion (3 mg/(kg·h) combined with remifentanil (0.5-1 g/(kg·h). Neuromuscular blockade was achieved by using 0.1-0.15 mg/kg pancuronium bromide or vecuronium. Meteraminol or phentolamine was used to maintain the systemic pressure between 50 and 60 mm Hg and when necessary; esmolol hydrochloride (11 mg/kg) was used to decrease the heart rate.

Surgical technique

The exposure of the heart was provided by median sternotomy. Conduits were harvested and prepared. CPB was instituted by an ascending aortic cannula and a 2-stage venous cannula in the right atrium. Heparin was given at a dose of 3000 IU/kg to achieve a target activated clotting time above 450 seconds. A standard circuit was used, including a tubing set, a roller pump, and a hallow fiber membrane oxygenator. The prime solution contained 1000 mL of Hartmann solution, 500 mL of gelofucine, 0.5g/kg of mannitol, 7 mL of 10% calcium gluconate, and 60 mg of heparin. Nonpulsatile flow was used. Moderate hypothermia or normotermia was employed. The distal anastomoses were constructed before the proximal anastomoses. The left anterior descending (LAD) coronary artery was revascularized first, with the internal thoracic artery (ITA), followed by revascularization of the circumflex (Cx) and right coronary arteries (RCAs). Regional myocardial immobilization was achieved with a suction stabilizer. During the construction of the anastomoses, target vessel homeostasis was obtained with the temporary proximal occlusion of the coronary artery, and a humidified carbon dioxide blower was used for better visualization. All distal anastomoses were made with running sutures of 7-0 or 8-0 polypropylene. The proximal anastomoses were performed with 5-0 or 6-0 polypropylene sutures under a partial occlusion clamp. After weaning from

Table 1. Preoperative data.

Variables	
Sex (M/F)	162/154
Age (mean, y)	68.1+/-4.8
Hypertension	133 (41.1 %)
Smoker habits	288 (91.1 %)
Diabetes mellitus	77 (24.3 %)
Hypercholesterolemia	145 (45.6 %)
Creatinine level > 1.6 mg/dL	34 (10.7 %)
COPD	102 (32.2 %)
CVD	14 (4.4 %)
PVD	35 (11 %)
Arrhythmias	24 (7.5 %)
Preoperative PTCA	189 (59.8 %)
Preoperative iABP	185 (51.3 %)
Stable angina	141 (44.6 %)
Unstable angina	175 (55.4 %)
Triple-vessel disease	201 (63.6 %)
Left main trunk stenosis >50%	114 (36 %)
LVEF (mean %)	27.7+/-4.7
LVEDD (mm)	64+/-3.2

CVD, Cerebrovascular disease; PVD, peripheral vascular disease; PTCA, percutaneous transluminal coronary angioplasty; IABP, intraaortic balloon pulsation; LVEF, left ventricul ejection fraction; LVEDD, left ventricul end diastolic diameter; COPD, chronic obstructive pulmonary disease.

CPB and decannulation, the heparin was reversed with protamine infusion (1:1.5). The intraoperative variables are given in **Table 2.**

Definitions and follow-up

Hospital mortality was defined as death of any reasons occurring within 30 days postoperatively. Perioperative AMI was defined as the appearance of new Q waves or a marked loss of R-wave forces and peak creatine phosphokinase fractions greater than 10% of total creatine phosphokinase. Low cardiac output syndrome (LCOS) was defined as cardiac index <2.0 L/(min · m^2) requiring pharmacologic support and/or IABP insertion. The IABP was kept for 3 (1) days. Postoperative renal dysfunction was defined as the increment of creatinine levels of 1 mg/dL or more, compared with the preoperative value. Neurological complications were defined as any transient or permanent neurological deficit occurring postoperatively. Gastrointestinal complications included confirmed the diagnosis of upper and lower gastrointestinal hemorrhage, intestinal ischemia, acute cholecytitis, and pancreatitis. All surviving patients underwent postoperative echocardiographic examination within postoperative 3 months. The mean follow-up time was 13 months (3-18 months).

RESULTS

All 316 acute coronary syndrome patients were operated for emergency multiple myocardial revascularization using the on-pump beating heart technique, without cardioplegic arrest by the same surgeon. A total of 155 patients (49.1%) were in these group with STEMI; 257 (81.3%) patients underwent percutaneous transluminal coronary angioplasty (PTCA) intervention preoperatively and nearly almost were unsuccessful or could not be completed due to unstable hemodynamic conditions. The preoperative data analysis is presented in **Table 1**. The time interval from the onset of AMI to CABG was 10 (2.2) hours. The mean number of grafts was 3.0 (0.6). Left ITA was used in 310 cases (98.1%) for LAD, and saphenous vein was used for other coronary artery revascularization. Coronary endarterectomy was performed in 66 cases (20.8 %) only on the side of anastomosis area. ITA grafts were harvested after CPB had been started. Six ITA grafts could not be harvested due to the unstable hemodynamic status of the patients. The LAD artery was revascularized in all patients. Diagonal branches were grafted in 262 patients (82.9 %), Cx marginal 1 or 2 branches were grafted in 82 (25.9 %) patients, and RCA was grafted in 155 (49 %) patients. Hospital mortality was 2.9 % (9 patients); 2 patients died in the operation room due

Table 2. Operative data.

Variables	
CPB time (s)	84+/-18
Number of distal anastomosis	3.0+/-0.6
LAD bypass	316 (100 %)
Diagonal branches	262 (82.9 %)
Cx bypass	66 (20.8 %)
RCA bypass	155 (49 %)
Coronary endarterectomy	60 (20.8 %)
LIMA usage	310 (98.1 %)

CBP: Cardiopulmonary bypass; LAD, left anterior decending coronary artery; Cx, circumflex; RCA, right coronary arteries; LIMA: left internal mammarian artery.

Table 3. Postoperative data.

Variables	
Hospital mortality (within 30 d) Operative mortality Early mortality (48 h) Later deaths	9 (2.9%) 4 (1.1%) 1 (3.1%) 2 (0.6%)
Perioperative MI	5 (1.5%)
New IABP insertion	43 (13.6%)
Duration of inotropic support (d)	4.1+/-3.1
LCOS	11 (3.4%)
Postoperative renal dysfunction(Cr>1.5 mg/dL)	8 (2.5%)
Postoperative hemodialysis	0
Pulmonary complications	9 (2.8%)
Neurological complications	7 (2.2%)
Gastrointestinal complications	2 (0.6%)
ICU stay (d)	3+/-2
Hospital stay (d)	7+/-4
Infectious complications	11 (3.4%)
Surgical revision for blood loss	18 (5.7%)
Postoperative blood loss> 1000 mL	31 (9.8%)
Postoperative LVEF (mean %)	39.2+/-4.7
Postoperative LVEDD (mm)	50+/-3.7

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

to ventricular fibrillation and global hypokinesia and 1 died because of intractable ventricular fibrillation on the second postoperative day. Coronary endarterectomy was performed in these 3 patients. Perioperative MI occurred in 2 patients in whom coronary endarterectomy was performed, and both were treated with the PTCA stent implantation of LAD or Cx. operative postoperative IABP was inserted in 43 (13.6%) patients due to global hypokinesia, ventricular arrhythmia, and hypotension intraoperatively. Although 64 (20.2%) patients had postoperative blood loss (more than 1000 mL), 36 (11.3%) of these patients had surgical revision because hemodynamic stability in these patients had not been granted. Six patients had LCOS after surgery. Four of them had renal dysfunction, but none of them needed hemodialysis. The mean intensive care unit stay was 3 (2) days, and the mean hospital length of stay was 7 (4) days. Postoperative neurological complications were diagnosed in 7 patients, pulmonary complications in 9 patients, and gastrointestinal complications in 2 patients. Transthoracic echocardiography was performed in all patients prior to discharge, and the mean LVEF was 39.2 (4.7%); LVEDD was 50.0 (3.7) mm. The mean follow-up time of the survivors was 3 to 18 months. The actuarial survival at 1, 12, and 18 months was 97%, 84%, and 77%, respectively.

DISCUSSION

The goals of myocardial revascularization are to preserve remaining myocardial function, prevent further functional deterioration, and recruit hibernating myocardium to improve ventricular functions.[9] Percutaneus catheter intervention techniques have recently became more popular and are now considered to be the first choice treatment for AMI. However, current indications for emergency CABG surgery in acute coronary syndrome patients are limited to those presenting with evolving myocardial ischemia refractory to optimal medical therapy, presence of left main stenosis and/or tripple-vessel disease, ongoing ischemia despite successful or failed PTCA, and complicated PTCA.[10]

With improved myocardial protection strategies, anesthesia, and surgical techniques, CABG is generally safe and efficient, although high mortality and morbidity are still documented in emergency conventional CABG after AMI.[11-14] The poor preoperative status of the patient including cardiogenic shock or organ failure and myocardial damage following cardioplegical arrest are responsible for this high rate. As an alternative to the conventional CABG for patients with AMI, on-pump beating heart CABG can be preferred. This technique keeps heart beating with the aid of CPB without aortic cross-clamping or cardioplegic arrest. The beating heart can preserve native coronary blood flow, which might reduce myocardial injury.[15] It has been demonstrated that maintaining the heart beat results in minimal myocardial edema and better left ventricular function. Another advantage of the on-pump beating heart surgery is that it allows optimal exposure of the coronary arteries.[16] This avoids extreme upward retraction of the heart, especially during revascularization of the Cx branches.[17] Various series of off-pump surgery demonstrated satisfactory clinical outcomes. OPCAB may be performed safely in hemodynamically stable acute coronary syndrome patients. Locker et al retrospectively reviewed 77 patients (40 off-pump CABG, 37 conventional CABG) with evolving acute coronary syndrome (<48 hours). Off-pump CABG was associated with lower in-hospital mortality (P=.015) but late mortality (6–66 months) was higher (P=.0066), and fewer distal anastomoses (P=.0001) were performed.[18]

Ben-Gal et al performed both an unmatched and a propensity-matched analyses of 1375 patients (unmatched: 221 off-pump CABG, 1154 conventional CABG; propensity matched: 220 off-pump CABG, 660 conventional CABG).[19] While propensity-matched off-pump CABG patients received fewer grafts compared with conventional CABG patients (2.8 [1.2] vs. 3.4 [1.03]; P<.001), no difference was seen in 30-day or late mortality by either analysis method. Furthermore, although fewer non-Q wave MI and bleeding events were seen with off-pump CABG at 30 days; no difference was seen in MI, stroke, acute kidney injury, or major adverse cardiac events in either the short or the long term. Unplanned reintervention was significantly higher at 30 days with off-pump CABG although no difference was observed at 1 year. Limited revascularization using off pump techniques provides long-term results, comperable to full revascularization with CPB, but at the cost of a threefold increase in reinterventions.[20]

In our study, patients had unstable angina, low ejection fraction, usually 3 or more vessel diseases, and required IABP frequently. The maintenance of cardiac functions during revascularization and possibility of complete revascularization are limited in these patients. Therefore, we preferred the on-pump beating heart CABG technique, which might constitute an alternative surgical approach in the highest risk patients in early post-MI period. In this study we documented our clinic's early outcomes with the on-pump beating heart CABG technique. A total of 131 patients had an emergency CABG for AMI, and 185 (51.3 %) of them were in cardiogenic shock and had IABP inserted preoperatively. We could not perform revascularization without

CPB in these patients. In the remaining 131 patients, complete revascularization would not be possible without CABG due to the presence of multivessel coronary disease, and the conventional CABG technique was too risky for such patients. The advantages of the on-pump beating heart technique were the reduction of the hemodynamic instability caused by surgical manupulations, absence of global myocardial ischemia during aortic cross-clamping, and absence of reperfusion after cardioplegic arrest. Postoperative temporary renal failure developed in 8 (2.5 %) patients, LCOS was diagnosed in 11 (3.4%) patients, and in-hospital mortality was 2.9%. The postoperative blood loss and the rate of surgical revision due to postoperative hemorrhage were higher than expected due to the extensive use of heparin and antiplatelet drugs preoperatively.

On the basis of these data, we thought that the on-pump beating heart revascularization technique can be a good choice for emergency CABG and high-risk patients with multivessel coronary artery disease. Additionally, we saw that the early revascularization decreases the occurrence of LCOS and related complications. Therefore, early revascularization is important, no matter which approach is used: surgicial or interventional.

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