Journal of
Cardio - Thoracic Medicine

http://jctm.mums.ac.ir

On-Pump Beating Myocardial Revascularization in Patients with Acute Coronary Syndrome

Behrouz Motahedi [1], Mahdi Kahrom *[1]

[1] Department of Cardiovascular Surgery, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.

ARTICLEINFO

Article type:
Original Article

Article history:
Received: 24 July 2022
Revised: 14 December 2022
Accepted: 21 December 2022

Keywords:
Coronary artery bypass grafting
Myocardial Revascularization
Acute coronary syndrome

ABSTRACT

Introduction: The on-pump beating heart technique for myocardial revascularization with a normothermic Cardiopulmonary bypass (CPB) represents a combination of standard on-pump and off-pump bypass techniques. The purpose of our study was to evaluate the outcome of patients with acute coronary syndrome undergoing on-pump beating coronary artery bypass grafting (CABG).

Methods: Between February 2020 and February 2021, 125 consecutive patients with acute coronary syndrome requiring coronary revascularization and not candidate for primary angioplasty or thrombolytic therapy, underwent on-pump beating myocardial revascularization. In this cohort study the primary inclusion criteria were the persistence of coronary artery disease (CAD) suitable for CABG and acute coronary syndrome. Our outcome variables included all-cause mortality, low cardiac output state, arrhythmia, postoperative myocardial infarction (MI), respiratory failure, stroke, ICU and total hospital stay.

Results: Mean age of patients was 59.11±9.81 years (range 33–84 years) and 68% of patients were male. Preoperative mean left ventricular ejection fraction was 43.61 ± 9.61 % (range 10-60 %) which improved to 46.71±8.41% postoperatively (p=0.010). The average number of graft per patient was 2.91±0.71 and complete revascularization was performed in 119 patients (95.2%). Mean ICU stay of patients was 2.11±1.41 (range 1–12) and mean hospital stay of patients was 6.11 ± 3.71 (range 5–15). Three patients (2.4%) died during recovery in the ICU due to acute cardiac failure.

Conclusion: On-pump beating CABG (OPBCABG) is an effective strategy with improved hospital outcome and can be a good alternative to conventional CABG and off-pump cardiac bypass surgery in acute coronary syndrome (ACS).

► *Motahedi, B., Kahrom, M. On-Pump Beating Myocardial Revascularization in Patients with Acute Coronary Syndrome. J Cardiothorac Med. 2022; 10(4): 1071-1077.*

Introduction

The prevalence of high risk patients candidate for coronary artery bypass grafting (CABG) is increasing and in these patients, choice of surgical strategy remains a challenge (1,2). CABG with heart-lung bypass and cardioplegic arrest (Conventional CABG) is the most common strategy. Using this strategy, peri-operative mortality rate is about 2%, and myocardial infarction (MI), renal failure needing dialysis or stroke developed in 5-7% of patients (3). Nevertheless, approximately one half of the coronary artery disease (CAD) patients present with acute MI or left ventricular

*Corresponding Author: Mahdi Kahrom , MD, Department of Cardiovascular surgery, Faculty of medicine, Mashhad University of Medical Sciences, Mashhad, Iran.Tel: 09155017276 , E.mail: kahrommh@mums.ac.ir .

dysfunction (LVD), who have additional risk for CABG surgery (4).

Despite a large number of studies and presence of different pump techniques, there is controversial debate whether CABG surgery should be performed with or without Cardiopulmonary bypass (CPB) (5). No surgical strategy was found perfect to be performed in all patients and the optimal technique used is still controversial.

Conventional CABG (CCABG) which is used routinely worldwide uses CPB and cardioplegic arrest to provide a stationary state and facilitate the operation. This surgical method leads to obligate duration of global myocardial ischemia that is partially decreased by cardioplegic cardiac arrest (6). Nonetheless this standard technique is still associated with some complications mostly due to the use of aortic X-clamping, cardioplegic cardiac arrest and extracorporeal circulation (7).

During the past two decades, interest has been raised in the off-pump coronary artery bypass grafting (OPCAB) technique, which avoids CPB, aortic cross-clamping, cardioplegic arrest, and global "ischemic time" with the specific purpose of decreasing the morbidity and mortality (8,9). Despite proved safety and efficacy of both CCABG and OPCAB in routine patients, under some conditions, using of both strategies are not feasible and even detrimental to the heart (10-12).

On-pump beating CABG (OPBCABG) surgery is the combination of both mentioned techniques, with maintenance of myocardial flow and empty heart beating during surgery, and seems to be beneficial for complete revascularization and suitable for high risk patients. The OPBCABG strategy can decrease the morbidity and mortality in such high risk group of patients (7). The goal of this cohort study is to evaluate the outcome of patients with acute coronary syndrome undergoing OPBCABG.

Materials and Methods

Out of 677 patients in our center operated for CABG from February 2020 to February 2021, 125 (18.5%) consecutive patients with acute coronary syndrome requiring coronary revascularization and not candidate for angioplasty or thrombolytic therapy, underwent on-pump beating CABG.

The basic inclusion criteria for our study were the diagnosis of CAD feasible for CABG on the coronary angiography and presence of acute coronary syndrome; including recent ST elevation or non ST elevation MI or unstable angina.

All patients were proved to have none of liver or renal disorder, blood disease, significant carotid stenosis or chronic obstructive pulmonary disease (COPD) before enrollment.

Preoperative coronary angiography and trans-thoracic echocardiography (TTE) were done in all patients.

Postoperatively, our outcome variables were low cardiac output condition, reoperation, serious arrhythmia, postoperative MI, respiratory failure, stroke, intra-aortic balloon pump (IABP) insertion, ICU and hospital length of stay, in-hospital and early mortality.

All the data were expressed as mean ± standard deviation. The clinical data were compared using the chi-square test, Mann-Whitney U test, and independent t-test when suitable. A p value < 0.05 was considered statistically significant.

After harvesting of the bypass conduits such as left internal mammary artery (LIMA) and the greater saphenous vein, CPB was started after injection of IV heparin at a dose of 300-400 IU/kg sufficient to rise the activated clotting time (ACT) to above 480 seconds before starting of CPB. All patients were cannulated in the standard protocol and CPB was established when the ACT was suitable with controlled blood flow at 30-50 ml/kg/min.

On the full (CPB) and beating heart, the conduits were distally anastomosed to the coronary arteries using Octopus device stabilizer (Medtronic Inc.). The goal of the surgery was to perform complete coronary revascularization in all patients.

After proximal anastomosis of conduits to ascending aorta, re-warming to 37 C was completed and CPB discontinued, protamine sulphate was administered to reverse systemic heparinization.

Results

Between February 2020 and February 2021, a total of 125 consecutive patients with acute coronary syndrome were enrolled for on-pump-beating heart coronary revascularization. Mean age of patients was 59.11 ± 9.81 years (range 33–84 years) and 68.0% of patients were male.

Preoperative mean left ventricular ejection fraction was 43.61 ± 9.61 % (range 10-60 %) which improved to 46.71±8.41% postoperatively (p=0.010). Demographic characteristics and patients' risk factors are shown in table 1. The greater part of our patients had three vessel disease (82.4%) followed by two vessel (16.0%) and single vessel disease (1.6%). Left main stem involvement was present in 22 patients (17.6%). Patients' inclusion criteria are shown in Table 2.

The average number of conduit used per patient was 2.91 ± 0.71 and the LIMA was grafted in 119 patients (95.2%). In six patients the mammary artery was not harvested due to the patient's hemodynamic instability. Complete revascularization was achieved in 119 patients (95.2%). The mean CPB and operative time were 60.12 ± 11.02 and 158.22 ± 32.20 minutes respectively (Table 3).

Table 1. Basic patients' characteristics.

CCS angina class	Number	Percent (%)
I	0	0
II	19	15.2
III	65	52.0
IV	41	32.8
LVEF		43.61 ± 9.61
Hypertension	76	60.8
Smoking	16	12.8
Addiction	29	23.2
Hypercholesterolemia	42	33.6
Diabetes mellitus (I&II)	44	35.2
Peripheral vascular disease	9	7.2
Prior myocardial infarction	71	56.8
Myocardial infarction < 7 days	37	29.6
Urgency	7	5.6
Emergency	43	34.4
Preoperative IABP	12	9.6
Left main stump disease	22	17.6
Three Vessel disease	103	82.4
Two Vessel disease	20	16.0
Single Vessel disease	2	1.6

Abbreviations: CCS: Canadian Cardiovascular Society Angina Class; **LVEF:** Left Ventricular Ejection Fraction; **IABP:** Intra-Aortic Balloon Pump.

Table 2. Patients' risk profile .

Patients' risk profile	Number	Percent (%)
U/A (unstable angina)	24	19.2
Severe left main stenosis (more than 70%)	22	17.6
Intractable ventricular arrhythmia	4	3.2
Early post-acute MI (ongoing chest pain)	37	29.6
Post PCI complication	17	13.6
Severe LV dysfunction (less than 35%)	44	35.2

Abbreviations: MI: Myocardial Infarction; **PCI:** Percutaneous Coronary Intervention.

IABP was inserted preoperatively in two patients and five other cases needed IABP support for low cardiac output condition in post operative course. Mean number of packed cell transfusion during hospital admitting was 2.21±0.71 units (range 0-6). Mean ICU stay of patients was 2.11 ± 1.41 days (range 1–12). Mean patients' hospital stay was 6.11 ± 3.71 days (range 5–15) and median length of stay was 5 days (Table 4).Three patients (2.4%) died during recovery in the ICU due to acute cardiac failure. The follow-up visit was inclusive for all 122 patients survived from operation with the median follow-up duration of 13 months.

Discussion

Acute coronary syndrome patients represent an important group of patients which are referred for urgent CABG, with early morbidity and mortality about 4 times those of elective and stable CAD patients (6). Complete myocardial coronary revascularization should be the main priority of the bypass grafting irrespective of the technique, as incomplete revascularization is considerably associated with post-operative low cardiac output syndrome, peri-operative MI, and mortality (3).

CCABG with cardiac arrest is still the standard and the most commonly used technique in coronary artery revascularization. Complications associated with this strategy are related to the inflammatory response, hypothermia, aortic cross clamping, use of cardioplegia and myocardial protection (10,11,13).

Table 3: Patients' Intraoperative data.

	Number	Percent (%)
No. of graft/patient	2.91 ± 0.71	
Use of LIMA	119	95.2
Use of veins	125	100
Left anterior descending artery	125	100
Diagonal branches	15	12.0
Marginal branches or Circumflex	115	92.0
Right coronary artery	118	94.4
Complete revascularization	119	95.2
Cardiopulmonary bypass time (min)	60.12 ± 11.02	
Operative time (min)	158.22 ± 32.20	

Abbreviation: LIMA: Left internal mammary artery

Table 4: Patients' Postoperative Morbidity and Mortality.

	Number	Percent (%)
30-Day Mortality	3	**2.4**
Re-exploration for bleeding	4	**3.2**
Intraoperative IABP	7	**5.6**
Sternal Infection	4	**3.2**
Atrial Fibrillation	10	**8.0**
Ventricular Arrhythmias	4	**3.2**
Myocardial infarction	5	**4.0**
CVA	1	**0.8**
Respiratory Failure	8	**6.4**
Acute Renal Failure	10	**8.0**
Estimated blood loss (milliliter)	530 ± 312	
Intensive care unit stay (days)	2.11 ± 1.41	
Hospital stay (days)	6.11 ± 3.71	

Abbreviations: IABP: Intra-Aortic Balloon Pump ; **CVA:** Cerebro-Vascular Accident.

Although low-risk cases undergoing CCABG with a minor risk of developing peri-operative side effects from applying of CPB and cardioplegic arrest, the high-risk group of patients with ACS and uncompensated heart failure is prone to complications of emergency surgery (7,14,15). Consequently, conventional CABG may not be the perfect strategy in this subgroup of unstable cases: in particular, aortic cross clamping and cardioplegic arrest have been proved as operative risk factors for morbidity and mortality in these patients (16,17).

Interest has reemerged in the OPCAB grafting technique. Moreover, avoidance of aortic cannulation, aortic manipulation and CPB during OPCAB would translate into decreased inflammatory response, coagulopathy, stroke, reduced morbidity and mortality (5).

Another drawback of performing an OPCAB approach is the obvious difficulty of the surgical grafting on the beating heart, especially in unstable and high risk patients due to hemodynamic deterioration (18). Despite the current interest in favor of OPCAB surgery in patients with stable CAD, there has always been a debate on which surgical technique is more superior to another, in decreasing the morbidity and mortality owing to coronary revascularization (3).

Similar early and late survivals are shown in different RCTs for both off-pump and CCABG. In contrast, patients undergoing OPCAB surgery appears to have reduced number of grafts and increased require repeating revascularization procedure (5, 19-21).

The major benefits of OPBCABG are the decreasing of the hemodynamic instability condition during cardiac manipulations, the absence of aortic X-clamping and reperfusion injury or myocardial stunning after cardioplegic cardiac arrest (7, 22, 23).

In this study, data was gathered from 125 patients with acute coronary syndrome (ACS) meeting our inclusion criteria. The 2.4% hospital mortality rate of patients shows that this high risk subgroup of patients with ACS can undergo coronary artery bypass surgery with a safe and good outcome.

During follow up visit, enhancement in LV ejection fraction after surgical bypass was clearly shown. Preoperative mean left ventricular ejection fraction was 43.61±9.61 % (range 10-60 %) which improved to 46.71±8.41% postoperatively (p=0.010).

According to available literature and our experience, conventional CABG on CPB and cardioplegic arrest in high-risk cases is related with high rate of mortality and morbidity (24,25). It is demonstrated that, myocardial protection strategies could not satisfactorily keep away from myocardial injury in these high risk group of patients undergoing CABG and may end to difficult weaning from CPB (25,26).

In conclusion, on-pump beating CABG (OPBCABG) is an effective method with improved hospital outcome and can be a good alternative to CCABG and OPCAB in ACS and, to our opinion, this strategy can end to satisfactory results.

The limitations to the present study were lack of control group to compare the outcome between two groups and use of only mortality and morbidity end points for evaluation of patient outcome. Other indices such as cardiac biomarkers would be effective analysis for evaluation of myocardial function after revascularization.

Conclusions

OPBCABG is an effective method with improved hospital outcome and can be an amazing substitute to conventional CABG and off-pump surgery in ACS.

Reference

1. Trachiotis GD, Weintraub WS, Johnston TS, Jones EL, Guyton RA, Craver JM. Coronary artery bypass grafting in patients with advanced left ventricular dysfunction. The Annals of thoracic surgery. 1998 Nov 1;66(5):1632-9.

2. Salehi M, Bakhshandeh A, Rahmanian M, Saberi K, Kahrom M, Sobhanian K. Coronary artery bypass grafting in patients with advanced left ventricular dysfunction: excellent early outcome with improved ejection fraction. The Journal of Tehran University Heart Center. 2016 Jan 1;11(1):6.

3. Lamy A, Devereaux PJ, Prabhakaran D, Taggart DP, Hu S, Straka Z, et al. Five-year outcomes after off-pump or on-pump coronary-artery bypass grafting. New England journal of medicine. 2016 Dec 15;375(24):2359-68.
4. Wang B, Cheng Z, Ge Z, Peng B, Zhao Z, Quan X. Level of perioperative B-type natriuretic peptide associates with heart function after on-pump coronary artery bypass graft surgery on a beating heart. Pakistan Journal of Medical Sciences. 2015 Mar;31(2):379.
5. Fudulu D, Benedetto U, Pecchinenda GG, Chivasso P, Bruno VD, Rapetto F, et al. Current outcomes of off-pump versus on-pump coronary artery bypass grafting: evidence from randomized controlled trials. Journal of thoracic disease. 2016 Nov;8(Suppl 10):S758.
6. Pegg TJ, Selvanayagam JB, Francis JM, Karamitsos TD, Maunsell Z, Yu LM, et al. A randomized trial of on-pump beating heart and conventional cardioplegic arrest in coronary artery bypass surgery patients with impaired left ventricular function using cardiac magnetic resonance imaging and biochemical markers. Circulation. 2008 Nov 18;118(21):2130-8.
7. Ferrari E, Stalder N, von Segesser LK. On-pump beating heart coronary surgery for high risk patients requiring emergency multiple coronary artery bypass grafting. Journal of Cardiothoracic Surgery. 2008 Dec;3(1):1-6.
8. Bergsland J, Hasnan S, Lewin AN, Bhayana J, Lajos TZ, Salerno TA. Coronary artery bypass grafting without cardiopulmonary bypass-an attractive alternative in high risk patients. European journal of cardio-thoracic surgery. 1997 May 1;11(5):876-80.
9. Cartier R, Brann S, Dagenais F, Martineau R, Couturier A. Systematic off-pump coronary artery revascularization in multivessel disease: experience of three hundred cases. The Journal of Thoracic and Cardiovascular Surgery. 2000 Feb 1;119(2):221-9.
10. Darwazah AK, Bader V, Isleem I, Helwa K. Myocardial revascularization using on-pump beating heart among patients with left ventricular dysfunction. Journal of Cardiothoracic Surgery. 2010 Dec;5(1):1-6.
11. Darwazah AK. Abu Sham 'a RA, Hussein E, Hawri MH, Ismail H. Myocardial revascularization in patients with low ejection fraction< or= 35%: effect of pump technique on early morbidity and mortality. J Card Surg. 2006;21:22-7.
12. Perrault LP, Menasché P, Peynet J, Faris B, Bel A, de Chaumaray T, Gatecel C, Touchot B, Bloch G, Moalic JM. On-pump, beating-heart coronary artery operations in high-risk patients: an acceptable trade-off?. The Annals of thoracic surgery. 1997 Nov 1;64(5):1368-73.
13. Rastan AJ, Bittner HB, Gummert JF, Walther T, Schewick CV, Girdauskas E, et al. On-pump beating heart versus off-pump coronary artery bypass surgery—evidence of pump-induced myocardial injury. European journal of cardio-thoracic surgery. 2005 Jun 1;27(6):1057-64.
14. Kirklin JK. Prospects for understanding and eliminating the deleterious effects of cardiopulmonary bypass. The Annals of thoracic surgery. 1991;51(4):529-31.
15. Ascione R, Lloyd CT, Underwood MJ, Lotto AA, Pitsis AA, Angelini GD. Inflammatory response after coronary revascularization with or without cardiopulmonary bypass. The Annals of thoracic surgery. 2000 Apr 1;69(4):1198-204.
16. Gaudino M, Glieca F, Alessandrini F, Nasso G, Pragliola C, Luciani N, et al. High risk coronary artery bypass patient: incidence, surgical strategies, and results. The Annals of thoracic surgery. 2004 Feb 1;77(2):574-9.
17. Légaré JF, Buth KJ, King S, Wood J, Sullivan JA, Friesen CH, et al. Coronary bypass surgery performed off pump does not result in lower in-hospital morbidity than coronary artery bypass grafting performed on pump. Circulation. 2004 Feb 24;109(7):887-92.
18. Ascione R, Caputo M, Angelini GD. Off-pump coronary artery bypass grafting: not a flash in the pan. The Annals of thoracic surgery. 2003 Jan 1;75(1):306-13.
19. Diegeler A, Börgermann J, Kappert U, Breuer M, Böning A, Ursulescu A, et al. Off-pump versus on-pump coronary-artery bypass grafting in elderly patients. New England journal of medicine. 2013 Mar 28;368(13):1189-98.
20. Lamy A, Devereaux PJ, Prabhakaran D, Taggart DP, Hu S, Paolasso E, et al. Off-pump or on-pump coronary-artery bypass grafting at 30 days. New England Journal of Medicine. 2012 Apr 19;366(16):1489-97.
21. Taggart DP, Altman DG, Gray AM, Lees B, Nugara F, Yu LM, et al. Effects of on-pump and off-pump surgery in the Arterial Revascularization Trial. European Journal of Cardio-Thoracic Surgery. 2015 Jun 1;47(6):1059-65.
22. Wan IY, Arifi AA, Wan S, Yip JH, Sihoe AD, Thung KH, et al. Beating heart revascularization with or without cardiopulmonary bypass: evaluation of inflammatory response in a prospective randomized study. The Journal of thoracic and cardiovascular surgery. 2004 Jun 1;127(6):1624-31.

23. Prifti E, Bonacchi M, Giunti G, Frati G, Proietti P, Leacche M, et al. Does on-pump/beating-heart coronary artery bypass grafting offer better outcome in end-stage coronary artery disease patients?. Journal of cardiac surgery. 2000 Nov;15(6):403-10.
24. Ascione R, Reeves BC, Taylor FC, Seehra HK, Angelini GD. Beating heart against cardioplegic arrest studies (BHACAS 1 and 2): quality of life at mid-term follow-up in two randomised controlled trials. European heart journal. 2004 May 1;25(9):765-70.
25. Afrasiabirad A, Safaie N, Montazergaem H. On-pump beating coronary artery bypass in high risk coronary patients. Iranian Journal of Medical Sciences. 2015 Jan;40(1):40.
26. Miyahara K, Matsuura A, Takemura H, Saito S, Sawaki S, Yoshioka T, et al. On-pump beating-heart coronary artery bypass grafting after acute myocardial infarction has lower mortality and morbidity. The Journal of thoracic and cardiovascular surgery. 2008 Mar 1;135(3):521-6.