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INTRODUCTION

It has been shown that unfavorable outcomes may be seen during conversions from off to on-pump coronary artery bypass grafting (CABG) in a clinical studies (1-10). These adverse outcomes include increased early (1-4,6-14) and late (2,3,8,10) mortality, myocardial infarction (4,14,15), stroke (3,6,7,16), increased need for intra-aortic balloon pump, longer intensive care unit (ICU) (13,14,16), and hospital stays (3,14-16), increased red blood cell (RBC) transfusion requirements (1,8,14-16) and more hospital readmissions (17) The overall conversion rate was found as 4.9% (18,19) in meta-analyses and ranged from 0-19.4% in published series whereas this rate was found as 2.2% in the Society of Thoracic Surgeons national database

reports (20). However, it remains unclear which risk factors are associated with the conversion and whether these conversions are potentially preventable. A variety of risk factors have been identified in the literature including poor coronary targets (21-23), low left ventricular ejection fraction (16,24), congestive cardiac failure (4,24), surgeon's experience (2,4,5,16), lack of a positioning device (7,13), and prior CABG (4,6). Herein, we retrospectively compared the effect of transverse and vertical anatomical position of the heart on the incidence of on-pump conversion during coronary surgery.

MATERIAL AND METHODS

The study was approved by the institutional ethics committee in 2009 (2009/172A). Informed consents were obtained from

Does the anatomical shape of the heart present as a risk factor for "off-pump" coronary surgery?

Abstract

Aim: Emergency conversion to on-pump during coronary surgery is known to increase morbidity and mortality in patients undergoing off-pump coronary surgery. We aimed to investigate the relation between the anatomical position of the heart and the incidence of conversion to on-pump coronary surgery.

Material and Methods: Four hundred patients, who underwent off-pump three-vessel coronary surgery during June 2010 and February 2020. The angle between the left anterior descending (LAD) artery and the left arm of the sternal retractor was used to identify the anatomical position of the heart intraoperatively after pericardiotomy. Patients were categorized as having either transvers (Position Angle > 45°, n:200) or vertical (Position Angle < 45°, n:200) heart.

Results: The conversion rate was 8.75% (35/400) in our study. Thirty-three of patients with transverse heart patients converted to on-pump surgery (16.5%), whereas the two patients (1%) in patients with vertical heart. The length of intensive care unit stay was longer in patients with conversion compared to the patients with no conversion (3.17±1.10 days and 1.11±0.11 days, respectively) (p=0.001). Inotropic support and blood transfusion requirements were higher in converted patients. The mortality rate was 14.2% in converted patients while non-converted patients had no mortality (p<0.001).

Conclusion: Conversion from off to on-pump during coronary surgery may cause high incidence of morbidity and mortality. Probable causes responsible for conversion should be predicted before making a decision for off-pump surgery. Anatomically transverse position of the heart may be considered as a potential predictor of conversion.

Keywords: Off-pump surgery, vertical heart, transverse heart

all patients. We have been performing routinely off-pump coronary surgery since September 2000. We have noticed that angle between LAD direction and left arm of sternal retractor is closely correlated to anatomical shape of heart. We have planned a comparative retrospective study and made descriptions of vertical and transverse heart. Converted patient numbers were extremely limited in current off-pump literature. We aimed 30 converted surgery for obtain strong information. We have reached 30 conversion in 185 transverse heart patients. We then continued our study until the number of patients in both groups reached 200. We included every patient who did not meet the exclusion criteria during the study period. We did not implement a special selection program

Patients

We have been performing off-pump CABG as our routine preference in hemodynamically stable patients since 2010. We have divided patients into the anatomical shape of heart. Transverse heart is defined as the angle of left anterior descending (LAD) artery direction to the left arm of the sternal retractor is more than 45 degree in neutral heart position (Figure 1). Vertical heart is defined as the angle of LAD artery direction to the left arm of the sternal retractor is between 0-45 degree in neutral heart position (Figure 2). Early conversion is defined as conversion before coronary arteriotomy (intramyocardial or small coronary arteries). Late conversion is defined as the conversion occurring just after coronary arteriotomy or during performing coronary anastomosis. We have retrospectively compared transverse heart patients [n=200] to vertical heart patients [n=200] for the off-to-on conversion requirement.

Exclusion Criterion

Isolated coronary bypass surgery was performed in all 400 patients. Additional cardiac surgery, patients suffering from moderate to severe degree mitral regurgitation, redo coronary surgery and patients with left ventricle ejection fraction (LVEF) less than 30% were excluded. Every patient without exclusion criteria was entered into the study. Big hearts (cardiothoracic index >50%) are also excluded our study. The early conversion was accepted as exclusion criteria. All patients were classified as late conversion group patients. All patients received at least one anastomosis at the circumflex region. Patients with isolated LAD and right coronary artery (RCA) disease were not included in the study due to the relatively low conversion rate. Patients characteristics were detailed in Table I. We can not identify transverse heart in the preoperative periods. We have to wait until pericardiotomy to identify heart anatomy.

Surgical Technique

All surgical procedures were performed by one surgeon (EK). Patients characteristics are summarized in Table I. Pump was ready but kept it dry. Median sternotomy was performed in all patients. Left internal thoracic artery (LITA) and Right internal

thoracic artery (RITA) grafts were harvested in usual fashion as well as radial artery (RA) and saphenous vein (SV) grafts. Heparin (2mg/kg) was administered before ligation of the distal part of the LITA and the activated clotting time (ACT) was maintained between 200-300 seconds during the operation. Right pleurotomy and a deep vertical pericardiotomy were performed to facilitate displacement of the heart into right thoracic cavity. Patients were put on Trendelenburg position to increase venous return to the heart. Epicardial-stabilizers were routinely used for all anastomosis. The suction paddles are placed adjacent to target coronary artery for optimal immobilization. Suction is activated in each paddle and fixed at the target artery with suction is -400mmHg. Several commercially available vacuum stabilizer devices and an apical vacuum devices were routinely used. Coronary arteries were encircled proximally and distally with silastic sutures. Coronary shunts were not routinely used. Additional intravenous heparin was administered (with an ACT>480 seconds), and procedure was converted to on-pump, when hemodynamic instability developed. Until 2013 LITA anastomosis was performed prior to Cx anastomosis. Then we changed our technique and performed Cx-region anastomoses first to avoid stretching of the LITA graft when deviating the heart to the right thoracic cavity. Right coronary artery and its branches revascularization were performed lastly. Graft blood flow rates (mL/min) were measured by using Doppler ultrasound after all anastomosis was completed. If ischemic collapse developed during distal anastomosis procedure we placed intracoronary shunt kept the heart neutral position and waited until maintaining hemodynamic stability. We routinely waited for at least five minutes until the signs of electrocardiogram recovered before a second intervention. If both ischemic and hemodynamic collapse persists, then we prefer converting to on-pump surgery. In the case of serious hemodynamic collapse during the waiting period, we performed a manual heart massage and placed a purse-string while the pump lines were prepared.

Statistical Analysis

Statistical IBM SPSS ver. 20.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Clinical datas were expressed as mean values standard deviation. Differences were analysed by using Fisher's exact test, χ^2 -test, unpaired Student's t-test and Mann-Whitney test. P value less than 0.05 ($p<0.05$) was considered significant.

RESULTS

Patient characteristics did not differ significantly between the groups (Table I). The mean number of grafts did not differ significantly in patients with transverse and vertical heart (3.1 and 3.2, respectively). Perioperative myocardial infarction rate was found significantly ($p=0.041$) higher on transverse heart (3 and 1 respectively). Persistent hemodynamic deterioration developed in 33 (16.5%) of transverse heart patients and we had to make conversion to on-pump surgery. Only two (1%) of vertical heart

patients required conversion due to ischemia. Mortality rate was 2% (4/200) in transverse heart patients and 0.5% (1/200) in the vertical heart patients (Table I). The average drainage amount was noted as 750±125ml in converted patients, whereas this amount was noted as 501±230ml in non-converted patients ($p=0.011$). The average packed blood transfusion was reported as 2,46±0.25 units in converted patients and 1.34±1.27 units in non-converted patients ($p=0.001$). There was a significant ($p=0.034$) difference between the two groups in terms of average Fresh Frozen Plasma transfusion requirement (1.68±0.32 and 1.27±1.13 respectively). Pharmacological inotropic support was required in 30 (85.7%) of the converted patients, but 55 (15%) of the non-converted patients required pharmacological inotropic support ($p<0.001$). An intra-

aortic balloon pump was placed in nine of the transverse heart patients and in two of the vertical heart patients ($p=0.001$). The average ventilation duration was 9.17±2.11 hours in converted patients, and 4.3±3.37 hours in non-converted patients ($p<0.001$). The average length of ICU stay was 3.17±1.10 days in converted patients, and 1.11±0.11 days in the non-converted patients. No deaths were recorded in non-converted patients but five (14.2%) patients died in converted patients (Table II). We routinely used LITA grafts for LAD, however LITA was anastomosed to the first diagonal artery in 23 patients. Innominate artery (IA) was used for proximal anastomosis in 2 patients due to porcelain ascending aorta.

Table 1. Preoperative and postoperative variables

Variable	Transverse Heart	Vertical Heart	P value
no	200	200	
Preoperative Variables (no and %)			
Female	77(38.5)	82(41)	0.815
Age	61.8±7.4	64.2±8.4	0.707
NYHA (1-4)	2.61±0.74	2.77±0.66	0.101
No. disease vessels	2.31±0.13	2.41±0.3	0.457
LMCA	31(15.5)	36(18)	0.774
Cardiomegaly	29(14.5)	24(12)	0.341
Diabetes	88(44)	86(43)	0.548
Hypertension	95(47.5)	101(50.5)	0.671
COPD	47(23.5)	41(20.5)	0.562
Preop-MI	66(33)	57(28.5)	0.101
Stroke	11(5.5)	10(5)	0.966
PVD	17(8.5)	14(7)	0.455
Postoperative Variables (no and %)			
Porcelain Aorta	1(0.5)	1(0.5)	0.978
Graft number(no)	3.15±1.1	3.24±0.9	0.351
LITA	188(94)	191(95.5)	0.944
RITA	11(5.5)	15(7.5)	0.765
Radial Artery	132(66)	127(63.5)	0.802
Saphenous Vein	200(100)	200(100)	0.742
Perioperative MI	3(1.5)	1(0.5)	0.041
RCA endarterectomy	3(1.5)	4(2)	0.532
New stroke	3(1.5)	2(1)	0.622
New renal failure	2(1)	3(1.5)	0.811
Post-op Atrial fibrillation	87(43.5)	80(40)	0.756
Re-exploration for bleeding	5(2.5)	3(1.5)	0.322
OFF-to-ON Conversion	33(16.5)	2(1)	<0.001
Death	4(2)	1(0.5)	<0.001

COPD=chronic obstructive pulmonary disease LITA= left internal thoracic artery LMCA=left main coronary artery MI=myocardial infarction; NYHA=New York Heart Association; PVD=peripheral vascular disease RITA= right internal thoracic artery, $p<0.05$ was considered significant, Clinical datas were expressed as mean values±standard deviation. Chi-square, Fischer exact test and Mann-Whitney U tests were used. Numbers and percentage are places same box respectively

Table 2. Comparison of converted to non-converted patients

Variable	Off-to-on Converted (N=35)	Off-to-on Non-Converted(N=365)	P value
Average drainage(mL)	750±125	501±230	0.011
Average Transfusion(unit)			
Blood	2.46±0.25	1.34±1.27	0.001
FFP	1.68±0.32	1.27±1.13	0.034
Inotrope requirement/%	30(85.7)	55(15)	<0.001
IABP	9	2	0.001
Average Ventilation time (h)	9.17±2.11	4.3±3.37	<0.001
Average ICU stay(day)	3.17±1.10	1.11±0.11	0.001
Average Hospital stay(day)	7.32±1.31	4.28±3.31	<0.001
Death /%	5/14.2%	0	<0.001

IABP=intra-aortic balloon pump, ICU=intensive care unit; FFP=fresh frozen plasma. $p<0.05$ was considered significant. Clinical datas were expressed as mean values±standard deviation. Chi-square, Fischer exact test and Mann-Whitney U tests were used

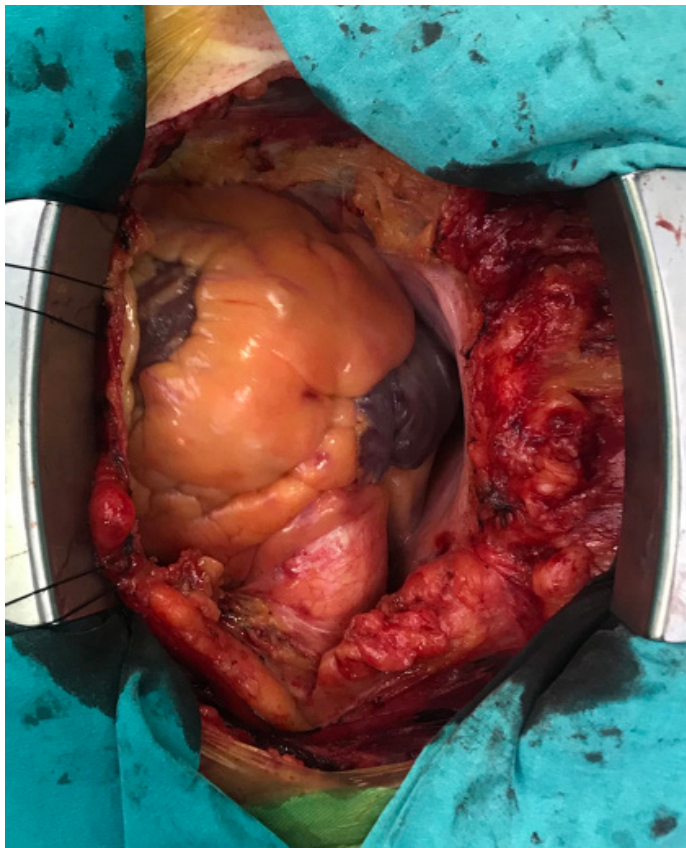


Figure 1. (INTRA-OPERATIVE PHOTOGRAPH) TRANSVERSE HEART is defined as the condition when the angle of left anterior descending artery direction to the left arm of the sternal retractor is more than 45 degree in neutral heart position



Figure 2. (INTRA-OPERATIVE PHOTOGRAPH) VERTICAL HEART is defined as the condition when angle of left anterior descending artery direction to the left arm of the sternal retractor is between 0-45 degree in neutral heart position. Left anterior descending artery completely is seen in this heart anatomy

DISCUSSION

According to our observations; Myocardial failure as a cause of mortality was seen in less than 50% of our patients. The other early deaths were mostly due to additional organ failures (such as renal, liver, lung failures, major stroke and excessive transfusion due to bleeding). Our patients' profiles have considerably changed in recent decades of CABG surgery. Elderly patients and co-existence of organ failure are common characteristics of our patients in recent years. Nowadays, percutaneous coronary interventions (PCI) are more worldwidely preferred in coronary patients. Thus more complicated cases in terms of limited runoff coronary vessels are more frequently encountered. Classical on-pump cardiac surgery has some deleterious effects due to extracorporeal perfusion and inadequate myocardial preservation which may lead to complications such as myocardial and brain ischemic injury, renal failure, and other organ deficiencies¹¹. Surgeons may prefer off-pump CABG surgery to avoid these complication risks and mortality. However, off-pump surgery has its difficulties. Myocardial ischemia and hemodynamic disturbance or both may cause serious complications during off-pump surgery. Especially surgery of the Cx region of coronary vessel surgery becomes much more difficult in hyperthrophied heart and transverse heart anatomy conditions (2-17). Despite all technical innovations, conversion from off-pump to on-pump may be required to perform complete myocardial revascularization. Many surgeons prefer incomplete myocardial revascularization to avoid complications during off-pump surgery. It's well known that incomplete myocardial revascularization may cause ischemic complications after surgery and patients need additional PCI interventions (20-24). The overall conversion rate was reported up to 19.4% (18-20). Edgerton JR. (4) reported that surgical experience was the most important factor of off-pump surgery. Our total conversion rate is 8.7% in 400 surgical procedures on three coronary vessel disease. But 33 converted patients had transverse heart anatomy (16.5%) . Our conversion rate in vertical heart patients was 1%. Conversion to on-pump surgery has some disadvantages except for early conversion conditions. Particularly, conversion in emergency conditions has multiple unfavorable effects and carries high morbidity and mortality risk. Multiorgan failure due to persistent ischemia and prolonged hypertension, increased transfusion requirements, and increased vulnerability to infection seems to be related to increased morbidity and mortality risk. Tabata M. (13) has reported a 14.3% operative mortality rate in patients undergoing emergency conversion whereas a 1.2% mortality rate in off-pump surgery group patients. Similar mortality rates were also reported in several studies (7-21). Rightward disposition of the heart may cause a different degree of mitral regurgitation. Severe mitral regurgitation due to cardiac displacement may cause acute pulmonary edema (13). Acute pulmonary edema occurs in the presence of prolonged cardiac displacement associated with mitral regurgitation leads to congestion in the left ventricle consequently causes severe hemodynamic instability. Tabata

M. (13) has shown that severe mitral regurgitation may develop even in the presence of a completely competent mitral valve preoperatively. The most comprehensive analysis of conversion mortality was reported by Edgerton JR (4). Their subgroup analyses showed a fivefold increase in mortality rate depending on whether the conversion was elective (6.1%) or emergency (32.1%), and almost 12-fold higher mortality rate depending on whether it was early (3.1%) or late (34.5%). As mentioned above, the myocardial injury and heart disposition are two principal causes of conversion to on-pump surgery. Myocardial ischemia was mainly dependent on the anastomosis site on the coronary artery and the degree of the coronary stenosis. Myocardial ischemia commonly occurred in proximal part of the coronary artery occlusion by silastic tapes. More proximal part preference meant more ischemia risk. Intracoronary shunts were frequently required in surgical procedures containing the main body of the RCA. Myocardial ischemia during silastic occlusion is much more common in patients with a relatively low degree of coronary stenosis. Predictors related to unfavorable outcomes of conversion to on-pump surgery are extremely important in terms of high morbidity and mortality risk of conversion. We found that the transverse heart was a relatively new predictor. Off-pump surgery is a relatively easy surgical procedure with a low conversion rate in the vertical heart. Disposition of the heart is mostly known as a mechanical hemodynamic deterioration factor in the transverse heart. Rightward disposition of the heart may cause right ventricle outflow tract and pulmonary artery kinking in transverse heart anatomy (25). Distortion of the heart may cause severe mitral regurgitation which results in the development of acute pulmonary edema (13). Our results showed that the transverse heart is likely to be a risk factor for conversion to the on-pump procedure.

LIMITATION

This study was not randomized prospective study. The groups were not completely matched in some ways prior to the surgery because of patient's were selected at operation based on the between the angle of LAD artery and left limb of sternal retractor. Unfortunately there is not any imaging technique that views the exact angle of LAD at the preoperative period. We can not perform intraoperative transesophageal echocardiography (TEE) to all patients. Intraoperative TEE would allow us information (such as mitral valve regurgitation, kinking of right ventricle and pulmonary artery, and contractility changes of heart sections) of cardiac anatomy during rightwardly deviation of the heart. To our knowledge, there were no descriptions of transverse heart and vertical heart in the literature. We aimed to give a new definition for the literature with this study. Also, we intended to determine the effect of shape of the heart as a predisposing factor for conversion (off-pump to on-pump). We just aimed to compare transverse and vertical heart anatomy for risk of conversion. Because of this reason we had not made multivariate analyses in this study. Other risk (predictor) factors such as big heart, small

coronary arteries, intramyocardial coronary arteries, low ejection period, mitral valve regurgitation and surgeon experience were already described. We had not required multivariate analyses.

CONCLUSION

Predictors likely to be responsible for conversion should be considered before making a decision for off-pump surgery. The transverse heart is a potential predictor for conversion and should be considered as an early conversion marker. Vertical and horizontal heart definition according to LAD direction is made for the first time with our study. The effect of transverse heart anatomy on conversion should be supported by multicenter studies.

Conflict of Interests: The author declares that there are no conflict of interests.

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Ethics committee approval: The study was approved by the institutional ethics committee in 2009 (2009/172A).

REFERENCES

1. MLegare JF, Buth KJ, Hirsch GM. Conversion to on pump from OPCAB is associated with increased mortality: results from a randomized controlled trial. *Eur J Cardio-Thoracic Surg.* 2005;27:296-301.
2. Novitzky D, Baltz JH, Hattler B, et al. Outcomes after conversion in the Veterans Affairs randomized on versus off bypass trial. *Ann Thorac Surg.* 2011;92:2147-54.
3. Chowdhury R, White D, Kilgo P, et al. Risk factors for conversion to cardiopulmonary bypass during off-pump coronary artery bypass surgery. *Ann Thorac Surg.* 2012;93:1936-41.
4. Edgerton JR, Dewey TM, Magee MJ, et al. Conversion in off-pump coronary artery bypass grafting: an analysis of predictors and outcomes. *Ann Thorac Surg.* 2003;76:1138-42.
5. Hemli JM, Patel NC, Subramanian VA. Increasing surgical experience with off-pump coronary surgery does not mitigate the morbidity of emergency conversion to cardiopulmonary bypass. *Innovations.* 2012;7:259-65.
6. Jin R, Hiratzka LF, Grunkemeier GL, Krause A. Aborted off-pump coronary artery bypass patients have much worse outcomes than on-pump or successful off-pump patients. *Circulation.* 2005;112:1332-7.
7. Patel NC, Patel NU, Loulmet DF, et al. Emergency conversion to cardiopulmonary bypass during attempted off-pump revascularization results in increased morbidity and mortality. *J Thorac Cardiovasc Surg.* 2004;128:655-61.
8. Reeves BC, Ascione R, Caputo M, Angelini GD. Morbidity and mortality following acute conversion from off-pump to on-pump coronary surgery. *Eur J Cardiothorac Surg.* 2006;29:941-7.
9. Soltoski P, Salerno T, Levinsky L, et al. Conversion to cardiopulmonary bypass in off-pump coronary artery by-pass grafting: its effect on outcome. *J Card Surg.* 1998;13:328-34.
10. Castellanos CLM, Carnero M, Cobiella FJ, et al. Off-pump to On-pump emergency conversion: incidence, risk factors, and impact on short and long-term results. *J Card Surg.* 2015;30:735-45.
11. Carrier M, Perrault LP, Jeanmart H, et al. Randomized trial comparing off-pump to on-pump coronary artery by-pass graft high-risk patients. *Heart Surg Forum.* 2003;6:E89-92.
12. Mathur AN, Pather R, Widjanarko J, et al. Off-pump coronary artery bypass: Sudbury experience. *Can J Cardiol.* 2003;19:1261-9.
13. Tabata M, Takanashi S, Horai T, et al. Emergency conversion in off-pump coronary artery bypass grafting. *Interact CardioVasc Thorac Surg.* 2006;5:555-9.
14. Vassiliades TA, Nielsen JL, Lonquist JL. Hemodynamic collapse during off-pump coronary artery bypass grafting. *Ann Thorac Surg.* 2002;73:1874-9.
15. Landoni G, Pappalardo F, Crescenzi G, et al. The outcome of patients requiring emergency conversion from off-pump to on-pump coronary artery bypass grafting. *Eur J Anaesthesiol.* 2007;24:317-22.
16. Hovakimyan A, Manukyan V, Ghazaryan S, et al. Predictors of emergency conversion to on-pump during off-pump coronary surgery. *Asian Cardiovas Thorac Ann.* 2008;16:226-30.
17. Li Z, Amsterdam EA, Danielsen B, et al. Intraoperative conversion from off-pump to on-pump CABG is associated with increased 30-days hospital readmission. *Ann Thorac Surg.* 2014;98:16-22.
18. Mukherjee D, Ashrafian H, Kourliouros A, et al. Intraoperative conversion is a cause of masked mortality in off-pump coronary artery bypass: A meta-analysis. *Eur J Cardiothorac Surg.* 2012;41:291-9.
19. Urso S, Sadaba JR, Pettinari M. Impact of off-pump to on-pump conversion rate on post-operative results in patients undergoing off-pump coronary artery bypass. *Interact CardioVasc Thorac Surg.* 2012;14:188-93.
20. Puskas JD, Edwards FH, Pappas PA, et al. Off-pump techniques benefit men and women and narrow the disparity in mortality after coronary bypass grafting. *Ann Thorac Surg.* 2007;84:1447-54.
21. Mukherjee D, Ahmed K, Baig K, et al. Conversion and safety in off-pump coronary artery bypass: a system failure

- that needs re-emphasis. *Ann Thorac Surg.* 2011;91:630-9.
22. Pullan M, Oo A, Poullis M. Off-pump conversion: In-hospital mortality and long-term survival. *Thorac Cardiovasc Surg.* 2017;65:296-301.
23. Lund O, Christensen J, Holme S, et al. On-pump versus off-pump coronary artery bypass: independent risk factors and off-pump graft patency. *Eur J Cardiothorac Surg.* 2001;20:901-7.
24. Mishra M, Shrivastava S, Dhar A, et al. A prospective evaluation of hemodynamic instability during off-pump coronary artery bypass surgery. *J Cardiothorac Vasc Anesth.* 2003;17:452-8.
25. Puskas JD, Williams WH, Duke PG, et al. Off-pump coronary artery bypass grafting provides complete revascularization with reduced myocardial injury, transfusion requirements, and length of stay: A prospective randomized comparison of 200 unselected patients undergoing off-pump versus conventional coronary artery bypass grafting. *J Thorac Cardiovasc Surg.* 2003;125:797-808.