Pleuropericardial window enhances surgery on beating heart – haemodynamic evidence

Okno osierdziowo-płucne ułatwia operację na bijącym sercu – parametry hemodynamiczne

Zbigniew Juraszyński[1], Anna Wojno[2], Piotr Szatkowski[2], Dariusz Zieliński[1], Zofia Dzielińska[3], Andrzej Biederman[1]

[1]1st Department of Cardiac Surgery, Institute of Cardiology, Warsaw, Poland
[2]Department of Anaesthesiology, Institute of Cardiology, Warsaw, Poland
[3]1st Department of Coronary Artery Disease, Institute of Cardiology, Warsaw, Poland

Kardiochirurgia i Torakochirurgia Polska 2010; 7 (4): 388–394

Abstract

Aim: The purpose of this study was to investigate the efficacy of techniques designed to minimize right heart compression and provide better exposure of the posterior wall vessels during cardiac surgery.
Material and methods: The study included 88 elective, low-risk patients with multivessel disease including the circumflex branches. All patients were analysed for changes in haemodynamic parameters. Patients were divided into three groups. In Group I (25 pts), measurements were obtained after exposure of the posterior wall with a pleuropericardial window and Trendelenburg position. In Group II (35 pts), measurements were taken after exposure of the posterior wall using three stabilizations and exposure methods (Octopus, Starfish, and deep pericardial sutures). In Group III (28 pts), measurements were taken after exposure of the posterior wall with a pleuropericardial window, Trendelenburg position, and inotropic support.
Results: The most significant changes in all three groups were observed during exposure of the posterior wall, with a considerable reduction in mean arterial pressure, stroke volume index, and cardiac index, and an increase in right atrial pressure. Trendelenburg positioning and opening the right pleura resulted in an increase in mean arterial pressure, stroke volume index, and cardiac index when the posterior wall was exposed.
Conclusion: Pleuropericardial window combined with the Trendelenburg manoeuvre might reduce compression of the right ventricle and haemodynamic compromise during anastomoses of posterior wall vessels. This simple technique enhances surgery on the beating heart.
Key words: haemodynamic, coronary artery disease, off-pump coronary artery bypass grafting.

Streszczenie

Cel: Celem niniejszej pracy było zbadanie skuteczności technik służących zminimalizowaniu kompresji prawego serca oraz uzyskaniu lepszego uwidocznienia naczyń tylnej ściany podczas chirurgii serca.
Materiał i metody: Badaniem objęto 88 planowych pacjentów małego ryzyka z chorobą wielonaczyniową obejmującą gałęzie okalające. Wszystkich pacjentów przeanalizowano pod kątem zmian w parametrach hemodynamicznych. Pacjentów podzielono na trzy grupy. W grupie I (25 pacjentów) pomiarów dokonano po uwidocznieniu tylnej ściany za pomocą okna osierdziowo-opłucnego w pozycji Trendelenburga. W grupie II (35 pacjentów) pomiarów dokonano po uwidocznieniu tylnej ściany przy zastosowaniu trzech metod stabilizacji i uwidaczniania: Octopus, Starfish oraz szwy osierdziowe (*deep pericardial sutures*). W grupie III (28 pacjentów) pomiarów dokonano po uwidocznieniu tylnej ściany za pomocą okna osierdziowo-opłucnego, w pozycji Trendelenburga i przy wsparciu inotropowym.
Wyniki: We wszystkich trzech grupach największe zmiany zaobserwowano podczas uwidocznienia tylnej ściany: znaczną redukcję średniego ciśnienia tętniczego, wskaźnika objętości wyrzutowej i wskaźnika sercowego oraz wzrost ciśnienia w prawym przedsionku. Ułożenie w pozycji Trendelenburga oraz otwarcie prawej opłucnej spowodowało wzrost średniego ciśnienia tętniczego, wskaźnika objętości wyrzutowej oraz wskaźnika sercowego przy uwidocznionej tylnej ścianie.
Wnioski: Okno osierdziowo-opłucne w połączeniu z manewrem Trendelenburga może zredukować kompresję prawej komory oraz upośledzenie hemodynamiczne podczas anastomozy naczyń tylnej ściany. Ta prosta technika usprawnia operacje na bijącym sercu.
Słowa kluczowe: hemodynamiczny, choroba wieńcowa, pomostowanie aortalno-wieńcowe bez krążenia pozaustrojowego.

Adres do korespondencji: Zbigniew Juraszyński, Alpejska 42, 04-628 Warsaw, Poland, tel. +48 22 343 42 11, fax +48 22 343 45 10,
Email: zjurasz@wp.pl

Introduction

Several randomized and observational studies have reported the superiority of coronary artery bypass grafting (CABG) procedure without the use of extracorporeal circulation (ECC) (off-pump) [1-4]. Wider use of this procedure is limited by difficulties with revascularization of the posterior wall, mainly due to haemodynamic compromise. The use of stabilizers has facilitated anastomosing within the posterior wall, but has not fully eliminated the haemodynamic disturbances that occur when the heart is exposed [5-9]. Poor late results of incomplete revascularization caused by difficulties in anastomosing within the posterior wall [10-12] prompt the search for methods providing stable haemodynamic conditions during complete off-pump revascularization.

Aim

To evaluate haemodynamic alteration during exposure of the posterior heart wall for off-pump revascularization with different methods of stabilization.

Material and methods

The study included 88 patients (66 men) aged 40–82 years (mean 61.9 yrs) who underwent elective complete off-pump revascularization including anastomoses on the posterior wall.

In all patients, a graft was made to the circumflex artery or its branches. The patients were divided into three groups according to the employed method of heart stabilization and exposure.

Intraoperative procedures

The following surgical techniques were used:

- The heart was dislocated into the right pleural cavity.
- Patient was placed in a Trendelenburg position.
- The operating table was then tilted towards the surgeon.
- Commercially available stabilizers were used.
- Dobutamine infusion was used for inotropic support.

The following haemodynamic parameters were recorded: heart rate (HR), arterial blood pressure (ABP), right atrial pressure (RAP), *pulmonary artery pressure (PAP), pulmonary wedge pressure (PWP), cardiac index (CI), stroke volume index (SVI), left ventricular stroke work index (LVSWI)*, right *ventricular stroke work index (RVSWI)*, systemic vascular resistance (SVR), and pulmonary vascular resistance (PVR). These haemodynamic parameters measured during posterior wall exposure with various methods of exposure and stabilization were compared with the baseline data obtained after opening the pericardium.

In Group I (25 patients), haemodynamic parameters were measured without the use of heart stabilizers as follows:

I. With open pericardium – reference position.
II. With posterior wall exposed.
III. With posterior wall exposed in the Trendelenburg position.
IV. With posterior wall exposed with the *pleuropericardial window.*
V. With posterior wall exposed with the *pleuropericardial window,* in the Trendelenburg position, and the operating table tilted towards the surgeon.

In Group II (35 patients), haemodynamic parameters were measured using three methods of heart exposure:

I. With open pericardium – reference position.
II. With posterior wall exposed with the aid of tissue stabilizer (Octopus Medtronic Inc. USA).
III. With posterior wall exposed with the aid of a Lima suture [13].
IV. With posterior wall exposed with the aid of 2 tissue stabilizers (Octopus and Starfish, Medtronic Inc. USA).
V. With posterior wall exposed with the aid of a stabilizer (Octopus Medtronic Inc. USA), *pleuropericardial window, and* Trendelenburg position.
VI. With posterior wall exposed with the aid of a Lima suture, *pleuropericardial window, and* Trendelenburg position.
VII. With posterior wall exposed with the aid of stabilizers (Starfish, Octopus Medtronic Inc. USA), *pleuropericardial window, and* Trendelenburg position.

In Group III (28 patients), the influence of dobutamine on haemodynamic parameters *was studied. Measurements were taken at the following points in the operation:*

I. With pericardium open – reference position.
II. With posterior wall exposed with the aid of a stabilizer (Octopus Medtronic Inc.).
III. With posterior wall exposed with the aid of a stabilizer (Octopus Medtronic Inc.), *pleuropericardial window, and* Trendelenburg position).
IV. With posterior wall exposed with the aid of a stabilizer (Octopus Medtronic Inc.) and dobutamine infusion of 3 µg/kg/min.
V. With posterior wall exposed with the aid of a stabilizer (Octopus Medtronic Inc.), *pleuropericardial window,* Trendelenburg position, and dobutamine infusion of 3 µg/kg/min.

The protocol of the study was approved by the local ethics committee and each patient gave informed consent to participate in the study.

Statistical analysis was performed using SPSS 12 software. Differences between continuous variables between groups were assessed using ANOVA analysis. Differences were considered statistically significant when $P < 0.05$.

Limitations of methodology

Compression and deformation of the right ventricle during exposure of the posterior cardiac wall may result in sporadic tricuspid valve incompetence. This can lead to an increase in right atrial pressure and falsify measurements obtained with the thermodilution method [14].

Results

In Group I, when the posterior wall was exposed (Position II), MAP (Fig. 1), CI (Fig. 2), SVI, LVSWI, and RVSWI decreased significantly compared to baseline.

In consecutive positions (III, IV, V), the implementation of planned manoeuvres resulted in significant improvements in haemodynamic parameters.

The best results, similar to baseline data, were observed in Position V, i.e. when the posterior wall was exposed with the aid of a *pleuropericardial window,* the Trendelenburg position, and tilting the operating table towards the surgeon.

In Group II, in Positions II, III, and IV, MAP (Fig. 3), CI (Fig. 4), SVI, LVSWI, and RVSWI decreased significantly. In Positions V, VI, and VII, MAP (Fig. 3), CI (Fig. 4), SVI, LVSWI, and RVSWI improved significantly and were similar to baseline. SVR decreased significantly. Other haemodynamic parameters (HR, RAP, PAP, PWP, and PVR) did not change significantly in either phase of the study.

In Group III, in Position II, MAP (Fig. 5), CI (Fig. 6), SVI, LVSWI, and RVSWI decreased significantly. In Position III, haemodynamic parameters tended to increase significantly when compared with Position II and similarly in Position IV; the most significant improvement was observed in Position V. In this position, haemodynamic parameters MAP (Fig. 5), CI (Fig. 6), SVI, LVSWI, and RVSWI were even better than in Position I. Other haemodynamic parameters, such as RAP, PAP, PWP, SVR, and PVR did not show statistically significant changes. Only in Positions IV and V, after dobutamine infusion, did HR increase significantly in comparison with the baseline value.

Discussion

Revascularization of the posterior cardiac wall requires rotation of the heart, which may lead to kinking of the great vessels and impaired outflow and inflow. This may cause adverse haemodynamic effects and ischaemia [8, 15] despite the fact that the coronary arteries are not mechanically deformed during heart exposure [5, 6]. A drop in perfusion pressure can be caused by bradycardia, arrhythmia, compression of the ventricles by stabilizers, or impaired inflow and/or outflow secondary to manipulation of the heart [16]. Numerous studies have shown that the haemodynamic instability in off-pump coronary artery bypass procedures results from right ventricle dysfunction caused by mechanical compression [5, 9, 17-19]. A similar result is observed in the case of the left ventricle [20, 21]. The most visible restrictive dysfunction appears during anastomosis of the posterior wall [5, 22]. Many different methods providing stable haemodynamic conditions during posterior wall revascularization have been proposed [5, 18, 23, 24].

The aim of the present paper was to identify a method providing optimal haemodynamic conditions during revascu-

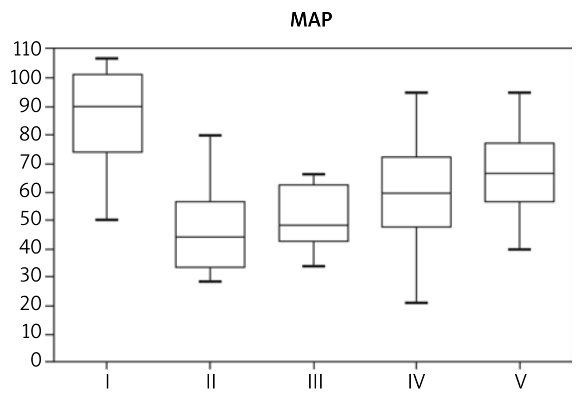

Fig. 1. Mean arterial pressure (MAP) in Group I (mm Hg)

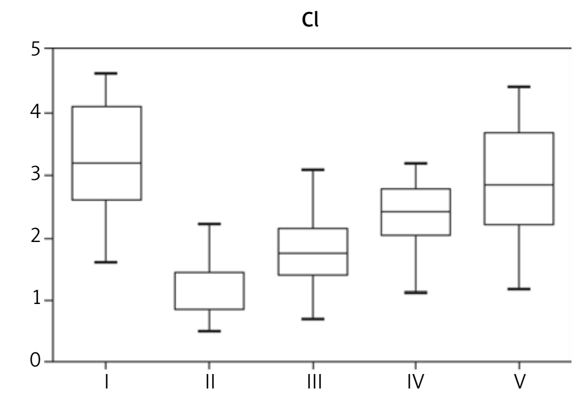

Fig. 2. Cardiac index (CI) in Group I (l/min/m^2)

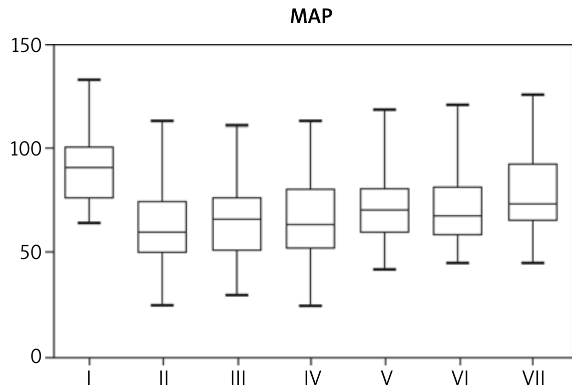

Fig. 3. Mean arterial pressure (MAP) in Group II (mm Hg)

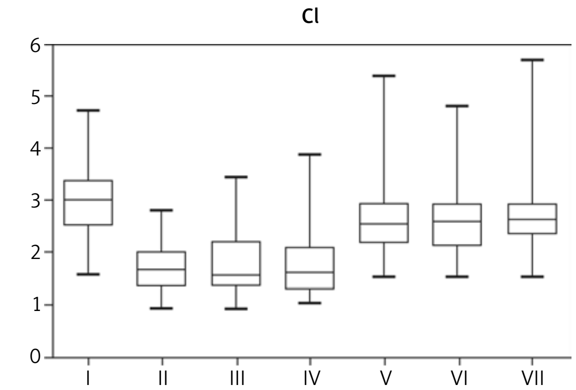

Fig. 4. Cardiac index (CI) in Group II (l/min/m^2)

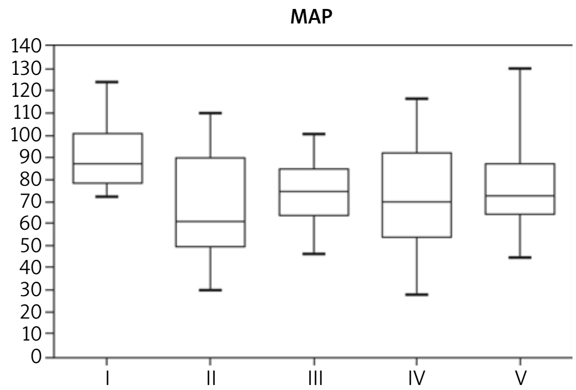

Fig. 5. Mean arterial pressure (MAP) in Group III (mm Hg)

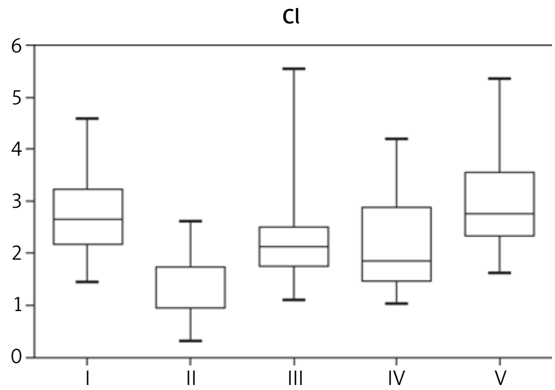

Fig. 6. Cardiac index (CI) in Group III ($l/min/m^2$)

larization of the posterior cardiac wall. The hypothesis was that the use of the *pleuropericardial window, which minimizes the effects of heart compression during exposure, and the* Trendelenburg manoeuvre, which enhances heart filling, would create the best haemodynamic conditions.

In Group I, haemodynamic parameters (Fig. 1, Fig. 2) were most improved with the *pleuropericardial window and the* Trendelenburg position combined with tilting the operating table towards the surgeon. The effect of the *pleuropericardial window was stronger than that of the* Trendelenburg position with a tilted table; these manoeuvres used in combination had additive effects.

According to Porat et al., heart exposure distorts both right ventricle outflow and inflow. A compromised right ventricle function results in decreased left ventricular filling [18]. Mathison et al. believe that the mode of heart exposure, Trendelenburg position, and tilting the table towards the surgeon as well as the creation of a *pleuropericardial window on the right side improve right ventricular inflow and systolic function. Subsequently, improved right ventricular ejection increases left ventricular filling pressure [19]. In Group II, haemodynamic parameters* (Fig. 3, 4) *deteriorated in all three methods of stabilization with a closed pleura when compared to the same methods of stabilization used with the pleuropericardial window, Trendelenburg position, and table tilted toward the surgeon.*

The stabilizations used currently facilitate exposure of the posterior heart wall. Each of the stabilization systems studied caused haemodynamic conditions to deteriorate. The use of stabilizers presses the heart against the rigid pericardial sac, which impairs ventricular diastolic function and, consequently, decreases ejection volume. Opening the right pleura improves ventricular compliance, resulting in an increased ejection volume. The combined effect of improved stroke volume in the pleuropericardial window group, compared to that with a closed pleura, results from increased filling pressures related to the Trendelenburg position and table tilting. Posterior wall exposure and the use of stabilizers primarily affect the thin-walled and low-pressure right ventricle [19].

Watters et al. used deep pericardial sutures, the Octopus vacuum stabilizer, and the Trendelenburg manoeuvre with the table tilted towards the surgeon *during posterior wall revascularization*. They also observed that the minute volume and ejection volume dropped most when anastomoses were made to the circumflex artery [7].

When the effect of the pleuropericardial window and dobutamine infusion (both in combination with the Trendelenburg position and table tilted towards the surgeon) on heart functioning was analysed in Group III, the use of dobutamine infusion during posterior wall exposure proved beneficial; however, the effect of the pleuropericardial window was stronger.

In clinical studies, many patients require inotropic support when anastomoses are performed in the posterior wall – 36% reported by Resano and 23% according to Mathison [25, 19].

Conclusions

Trendelenburg positioning and tilting of the table towards the operator together with the creation of a pleuropericardial window resulted in an improvement of haemodynamic conditions when the posterior cardiac wall was exposed. These manoeuvres facilitate complete off-pump revascularization in stable haemodynamic conditions.

References

1. Raja SG, Dreyfus GD. Off-pump coronary artery bypass surgery: to do or not to do? Current best available evidence. J Cardiothorac Vasc Anesth 2004; 18: 486-505.
2. Angelini GD, Taylor FC, Reves BC, Ascione R. Early and midterm outcome after off-pump and on-pump surgery in Beating Heart Against Cardioplegic Arrest Studies (BHEACAS1 and 2): a pooled analysis of two randomized controlled trials. Lancet 2002; 359: 1194-1199.
3. Hernandez F, Cohn WE, Baribeau YR, Tryzelaar JF, Charlesworth DC, Clough RA, Klemperer JD, Morton JR, Westbrook BM, Olmstead EM, O'Connor GT; Northern New England Cardiovascular Disease Study Group. In Hospital Outcomes of Off-Pump versus On-Pump Coronary Artery Bypass Procedures. A Multicenter Experience. Ann Thorac Surg 2001; 72: 1528-1534.
4. Puskas JD, Williams WH, Duke PG, Staples JR, Glas KE, Marshall JJ, Leimbach M, Huber P, Garas S, Sammons BH, McCall SA, Petersen RJ, Bailey DE, Chu H, Mahoney EM, Weintraub WS, Guyton RA. Off-pump coronary artery bypass grafting provides compete revascularization with reduced myocardial injury, transfusion requirements, and length of stay: A prospective randomized comparison of two hundred unselected patients undergoing off-pump versus conventional coronary artery grafting. J Thorac Cardiovasc Surg 2003; 125: 797-808.

5. Grundeman PF, Borst C, van Herwaarden JA, Mansvelt Beck HJ, Jansen EW. Hemodynamic Changes During Displacement of the Beating Heart by The Utrecht Octopus Method. Ann Thorac Surg 1997; 63: 88-92.
6. Burfeind WR, Duhaylongsod FG, Samuelson D, Leone BJ. The effects of mechanical cardiac stabilization on left ventricular performance. Eur J Cardio-thorac Surg 1998; 14: 285-289.
7. Watters MP, Ascione R, Ryder IG, Ciulli F, Pitsis AA, Angelini GD. Hemodynamic changes during beating heart coronary surgery with the “Bristol Technique”. Eur J Cardio-thorac Surg 2001; 19: 34-40.
8. Grundeman PF, Borst C, van Herwaarden JA, Verlaan CW, Jansen EW. Vertical displacement of the beating heart by the Octopus stabilizer: influence on coronary flow. Ann Thorac Surg 1998; 65:1348-1352.
9. Grundeman PF, Borst C, Verlaan CW, Meijburg H, Moues CM, Jansen EW. Exposure of circumflex branches in the tilted, beating porcine heart: echocardiographic evidence of right ventricular deformation and the effect of right or left bypass. J Thorac Cardiovasc Surg 1999; 118: 316-323.
10. Jones EL, Weintraub WS. The importance of completeness of revascularization during long-term follow-up after coronary artery operations. J Thorac Cardiovasc Surg 1996; 112: 227-237.
11. Czerny M, Baumer H, Kilo J, Zuckermann A, Grubhofer G, Chevtchik O, Wolner E, Grimm M. Complete Revascularization in Coronary Artery Bypass Grafting With and Without Cardiopulmonary Bypass. Ann Thorac Surg 2001; 71: 165-169.
12. Bell MR, Gersh BJ, Schaff HV, Holmes DR Jr, Fisher LD, Alderman EL, Myers WO, Parsons LS, Reeder GS. Effect of completeness of revascularization on long-term outcome of patients with three-vessel disease undergoing coronary artery bypass surgery. A report from the Coronary Artery Surgery Study (CASS) registry. Circulation 1992; 86: 446-457.
13. de Carvalho Lima R, de Escobar MA, Diniz R, de Alencar França NA, Cabral E, da Luz J. How much myocardial revascularization can we do without extracorporeal circulation? Heart Surg Forum 2002; 5: 163-167.
14. Velissaris T, Tang A, Jonas M, Ohri S. Hemodynamic changes during off-pump surgery. Eur J Cardiothorac Surg 2002; 22: 852.
15. Couture P, Denault A, Limoges P, Sheridan P, Babin D, Cartier R. Mechanisms of hemodynamic changes during off-pump coronary artery bypass surgery. Can J Anaesth 2002; 49: 835-849.
16. Puskas JD, Vinten-Johansen J, Muraki S, Guyton RA. Myocardial protection for off-pump coronary artery bypass surgery. Sem Thorac Cardiovasc Surg 2001; 13: 82-88.
17. Nierich AP, Diephuis J, Jansen EW, Borst C, Knape JT. Heart displacement during off-pump CABG: how well is it tolerated? Ann Thorac Surg 2000; 70: 466-472.
18. Porat E, Sharony R, Ivry S, Ozaki S, Meyns BP, Flameng WJ, Uretzky G. Hemodynamic changes and right heart support during vertical displacement of the beating heart. Ann Thorac Surg 2000; 69: 1188-1191.
19. Mathison M, Edgerton JR, Horswell JL, Akin JJ, Mack MJ. Analysis of haemodynamic changes during beating heart surgical procedures. Ann Thorac Surg 2000; 70: 1355-1361.
20. Do QB, Goyer C, Chavanon O, Couture P, Denault A, Cartier R. Hemodynamic Changes during off-pump CABG surgery. Eur J Cardiothorac Surg 2001; 21: 390-395.
21. Torracca L, Schreuder JJ, Quarti A, Ismeno G, Franzé V, Alfieri O. Acute Effects of Beating Heart Coronary Surgery on Left Ventricular Performance. Ann Thorac Surg 2002; 74: 1348 -1352.
22. Bisvas S, Clements F, Diodato L, Hughes GC, Landolfo K. Changes in systolic and diastolic function during multivessel off-pump CABG. Eur J Cardio-thorac Surg 2001; 20: 913-917.
23. Cartier R, Blain R. Off-pump Revascularization of the Circumflex Artery: Technical Aspect and Short-Term Results. Ann Thorac Surg 1999; 68: 94-99.
24. Shinn HK, Oh YJ, Kim SH, Lee JH, Lee CS, Kwak YL. Evaluation of serial hemodynamic changes during coronary artery anastomoses in patients undergoing off-pump coronary artery bypass graft surgery: initial experiences using two deep pericardial stay sutures and octopus tissue stabilizer. Eur J Cardiothorac Surg 2004; 25: 978-984.
25. Resano FG, Stamou S.C., Lowery RC, Corso PJ. Complete myocardial revascularization on the beating heart with epicardial stabilization: anesthetic consideration. J Cardiothorac Vasc Anesth 2000; 14: 534-539.