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COMPARISON OF MYOCARDIAL PROTECTION EFFECTS BETWEEN SEVOFLURANE INHALATION ANESTHESIA AND PROPOFOL TOTAL INTRAVENOUS ANESTHESIA IN OFF-PUMP CORONARY ARTERY BYPASS SURGERY: A MULTICENTER STUDY

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Abstract

Introduction: This study aimed to compare the myocardial protective effects of sevoflurane and propofol in patients undergoing Off-Pump Coronary Artery Bypass Grafting (OPCAB). Both anesthetic agents are commonly used in cardiac surgery; however, their relative efficacy in myocardial protection remains unclear. **Methods**: A total of 36 patients scheduled for elective OPCAB surgery were randomly assigned to two groups: 18 patients received sevoflurane, and 18 received propofol as anesthetic agents. Myocardial injury was assessed by measuring serum CK-MB levels at three time points: pre-induction (T0), 10 h post-surgery (T1), and 24 h post-surgery (T2). Left ventricular function was evaluated by measuring the ejection fraction (EF) preoperatively and postoperatively. Hemodynamic parameters (heart rate, mean arterial pressure, and central venous pressure) were monitored throughout the surgery. Postoperative recovery was assessed by measuring the duration of mechanical ventilation, ICU stay, and hospital stay. Statistical comparisons were made using appropriate tests (t-test, Mann-Whitney, and chi-square) with significance set at $p < 0.05$. **Results**: No significant differences were found in CK-MB levels between the sevoflurane and propofol groups at any of the three time points (T0, T1, and T2), indicating equivalent myocardial protection in both groups. The mean CK-MB values at T0, T1, and T2 were comparable between the sevoflurane (19.61 ± 88.081, 74.83 ± 70.503, 49.06 ± 44.421, respectively) and propofol groups (21.72 ± 10.532, 56.28 ± 32.807, 49.00 ± 29.019, respectively). Similarly, ejection fraction values were similar between the two groups preoperatively (sevoflurane: 50.01 ± 14.907%, propofol: 52.67 ± 13.676%) and postoperatively (sevoflurane: 50.72 ± 12.027%, propofol: 49.72 ± 12.136%). The hemodynamic parameters (heart rate, mean arterial pressure, and central venous pressure) were stable and comparable between the groups. Postoperative recovery outcomes, including mechanical ventilation duration, ICU stay, and hospital stay, were similar between the two groups. **Conclusion**: Sevoflurane and propofol provided equivalent myocardial protection during OPCAB surgery. These findings suggest that either anesthetic agent can be safely and effectively used for anesthesia management in OPCAB procedures without significant differences in myocardial injury or cardiac function.

Keywords: ***Sevoflurane, Propofol, Myocardial protection, OPCAB, CK-MB, Ejection***

INTRODUCTION

Coronary artery disease (CAD) is one of the leading causes of mortality in Indonesia. According to the 2018 Basic Health Research (Riset Kesehatan Dasar) data, the prevalence of heart disease based on physician diagnosis is 1.5%, with the highest rates observed in North Kalimantan (2.2%), Yogyakarta Special Region (2%), and Gorontalo (2%) [1]. Additionally, there has been a noted increase in the prevalence of heart attacks among individuals under 40 years of age, rising by 2% annually from 2000 to 2016 [2–4]. One of the surgical interventions for treating CAD is Coronary Artery Bypass Grafting (CABG). In Indonesia, the incidence of CABG procedures is notably high, with a continuous increase in the number of patients annually. However, specific epidemiological data on the number and distribution of CABG surgeries in Indonesia remain limited. In cases where coronary artery occlusions cannot be addressed by stenting, revascularization through surgical bypass is required to restore blood flow. CABG using cardiopulmonary bypass (CPB) involves halting the heart during coronary implantation. During this procedure,

myocardial preservation must be maintained using cardioplegia solutions, although ischemia often occurs and is frequently monitored by the duration of the ischemia [4]. Myocardial injury during cardiac surgery is typically mild; however, severe injury can lead to fatal complications. Over the last 50 years, numerous therapeutic strategies have been explored and developed to provide myocardial protection during cardiac surgery. Myocardial protection aims to shield the heart from ischemic and reperfusion injuries during surgery. Effective myocardial protection significantly improves the patient's heart condition and enhances their quality of life after surgery. Conversely, inadequate myocardial protection can result in worsened outcomes, often leading to patient death postoperatively [5–8].

To reduce the high mortality and morbidity rates, strategies to mitigate complications, such as organ dysfunction and systemic inflammation related to CPB use, as well as to shorten ischemic time, are crucial in CABG procedures [9]. Off-pump coronary artery bypass (OPCAB) is a technique developed to address these concerns. In this procedure, coronary bypass is performed without halting the heart or utilizing CPB. The heart continues to beat during the vascular grafting process, which is believed to prevent ischemia during surgery. This technique avoids cellular damage, inflammation, and organ dysfunction, which are common complications associated with CPB. However, OPCAB does not employ specific myocardial protection strategies, as seen in on-pump CABG procedures. During graft implantation, the heart axis is altered using apical suction and stabilizers, which may lead to hypotension and myocardial injury. This injury can result in myocardial dysfunction, as evidenced by increased biomarker release, such as troponin and CK-MB. Therefore, alternative methods for myocardial protection during OPCAB are necessary. Some intravenous and inhalational anesthetics have shown potential as organ-protective agents [10–12].

Research by Liling Jia et al. (2024) indicated that sevoflurane inhalation anesthesia could improve perioperative hemodynamic stability, provide myocardial protection, and reduce perioperative adverse cardiac events in elderly patients with diabetes undergoing noncardiac surgery. Sevoflurane, an inhalational anesthetic, possesses ischemic preconditioning effects that offer myocardial protection, whereas propofol mitigates free radical damage and provides myocardial protection [13,14]. Despite numerous studies evaluating the effects of sevoflurane and propofol individually on cardiac surgery, direct comparative studies in CABG patients remain limited.

METHOD

This study included adult patients who underwent elective Off-Pump Coronary Artery Bypass Grafting (OPCAB) surgery. The selection of participants was based on specific inclusion and exclusion criteria to ensure the relevance and validity of the findings. The inclusion criteria required participants to be adults aged ≥18 years who were scheduled for elective OPCAB surgery. Additionally, the study included patients who received either volatile anesthesia with sevoflurane or total intravenous anesthesia (TIVA) with propofol during the procedure. Patients who meet these criteria will be randomly assigned to one of two groups based on the type of anesthesia administered.

The exclusion criteria were as follows: patients undergoing emergency surgery, redo surgeries, those with unstable cardiovascular conditions preoperatively, and those with known allergies to sevoflurane or propofol. Patients requiring preoperative inotropic or vasopressor support were also excluded from this study. Furthermore, the dropout criteria included patients whose surgery was converted to on-pump procedures or those who experienced perioperative mortality. This rigorous selection process ensured the homogeneity and reliability of the sample for comparison between the two anesthetic agents used in the study.

This study employed a randomized controlled trial (RCT) design to investigate the effects of sevoflurane and propofol on myocardial injury biomarkers and left ventricular function in patients undergoing OPCAB surgery. The subjects will be randomized into two distinct groups based on the type of anesthetic agent used: Group A (sevoflurane) and Group B (propofol). The primary outcomes of this study were changes in CK-MB levels and ejection fraction (EF), both measured preoperatively and 24 h postoperatively. This study will focus on comparing these outcomes between the two groups, with the hypothesis that the type of anesthetic agent may influence post-surgical myocardial injury markers and cardiac function.

The sampling technique used is consecutive sampling, where each patient who meets the inclusion and exclusion criteria will be recruited sequentially based on their arrival at the hospital. Participants were randomized using a computer-based random number generator to ensure unbiased allocation into the two groups. To determine the appropriate sample size, a power calculation was conducted with a confidence level of 95% and a power of 90%. Based on these parameters, the required sample size was calculated to be 36 participants, with 18 participants in each group. This ensured sufficient statistical power to detect meaningful differences between the two groups. Prior to initiating the study, ethical approval was obtained from the institutional review board, and all participants provided informed consent. The research procedure began with a preoperative assessment, in which baseline measurements,

including CK-MB levels and ejection fraction, were obtained. Following the induction of anesthesia, the patients will receive either sevoflurane or propofol according to group allocation. The anesthesia regimen for all patients included a standard induction protocol with fentanyl, midazolam, propofol, and rocuronium, followed by maintenance with either sevoflurane or propofol, depending on the assigned group.

During the study, blood samples for CK-MB analysis were collected at three time points: preoperatively, 10 h postoperatively, and 24 h postoperatively. Additionally, transthoracic echocardiography will be used to assess ejection fraction at baseline and 24 h following surgery. Data collection will be handled carefully to ensure that all measurements are accurate and complete. Data will be entered into statistical software for analysis, with checks in place to ensure completeness and accuracy.

The data collected will be thoroughly processed to ensure validity. Descriptive statistics will be used to summarize patient characteristics and baseline variables. Continuous variables, such as age, weight, and ejection fraction, will be presented as means and standard deviations, whereas categorical variables will be summarized as frequencies and percentages. Comparisons between the two groups will be made using appropriate statistical tests, including the independent t-test for normally distributed data and the Mann-Whitney U test for non-normally distributed data. For paired data, paired t-tests or Wilcoxon signed-rank tests will be applied based on the distribution of the data.

For categorical data, chi-square tests will be used, with Fisher's exact test applied when necessary for 2×2 tables. Covariate analysis will be performed using regression models to account for potential confounding variables, such as age, sex, and comorbid conditions. The significance level for all tests will be set at $p \leq 0.05$. All statistical analyses will be conducted using SPSS version 26.0, and the results will be interpreted in the context of clinical and statistical significance.

This study adhered to the ethical guidelines set forth by the relevant institutional ethics review boards. The research protocol will be submitted for review and approval before the recruitment of participants. Informed consent will be obtained from all participants to ensure that they are fully aware of the study's aims, potential risks, and benefits. Confidentiality will be maintained at all stages of the study, with participant data anonymized and stored securely. Furthermore, participants will be informed of their right to withdraw from the study at any time without negative consequences. Ethical considerations are integral to the conduct of this study, ensuring respect for patient autonomy and privacy throughout the research.

RESULTS

This study will be conducted on patients undergoing Off-Pump Coronary Artery Bypass Grafting (OPCAB) surgery at RSUP Dr. Hasan Sadikin Bandung and RS Santosa Central Bandung from March to May 2025. A total of 36 patients met the inclusion and exclusion criteria, and each patient underwent measurements of CK-MB levels pre-induction (T0), 10 h post-surgery (T1), and 24 h post-surgery (T2), as well as assessments of ejection fraction (EF) preoperatively and postoperatively. The patients were divided into two groups: sevoflurane and propofol, each consisting of 18 patients.

The general characteristics of the participants, including age, sex, weight, height, and comorbidities, were compared between the Sevoflurane and Propofol groups. The demographic and clinical characteristics are presented in Table 1.

In the Sevoflurane group, the average age of patients was 63.28 ± 7.086 years, with a male predominance (83.3%) and a weight of 68.61 ± 14.940 kg. The average height was 164.00 ± 8.437 cm, and the most common comorbidity was hypertension (77.8%). In the Propofol group, the average age was lower at 58.11 ± 8.080 years, with a male predominance (72.2%) and weight of 67.67 ± 13.079 kg. The average height was 164.17 ± 8.291 cm, and the most common comorbidity was hypertension (72.2% of patients).

Statistical analysis revealed a significant difference in age ($p = 0.049$), with the sevoflurane group being older than the propofol group. However, there were no statistically significant differences in sex, weight, height, or comorbidities between the two groups ($p > 0.05$).

Table 1 Comparison of Patient Characteristics Between the Sevoflurane and Propofol Groups

Variable	Sevoflurane (N=18)	Propofol (N=18)	P-Value
Age	63.28 ± 7.086	58.11 ± 8.080	0.049*
Gender			0.691
Male	15 (83.3%)	13 (72.2%)	
Female	3 (16.7%)	5 (27.8%)	
Weight	68.61 ± 14.940	67.67 ± 13.079	0.841

Height	164.00 ± 8.437	164.17 ± 8.291	0.673
Comorbidities			
Hypertension	14 (77.8%)	13 (72.2%)	1.000
Diabetes Mellitus	2 (11.1%)	4 (22.2%)	0.658
Stroke	1 (5.6%)	1 (5.6%)	1.000

Note: Data were analyzed using the t-test for normally distributed data and the Mann-Whitney U test for non-normally distributed data. Categorical data were analyzed using the Chi-Square or Fisher's exact test when the chi-square assumptions were not met. The significance level was set at $p<0.05$.

CK-MB Levels at Different Time Points

Table 2 compares CK-MB levels at three time points (pre-induction (T0), 10 h post-surgery (T1), and 24 h post-surgery (T2]) between the Sevoflurane and Propofol groups. The statistical analysis of these data is provided in the table.

Table 2 Comparison of CK-MB Levels at T0, T1, and T2 Between the Sevoflurane and Propofol Groups

Variable	Sevoflurane (N=18)	Propofol (N=18)	P-Value
CK-MB T0	19.61 ± 88.081	21.72 ± 10.532	0.673
CK-MB T1	74.83 ± 70.503	56.28 ± 32.807	0.888
CK-MB T2	49.06 ± 44.421	49.00 ± 29.019	0.239

For CK-MB levels, the sevoflurane group had an average value of 19.61 ± 88.081 at T0, 74.83 ± 70.503 at T1, and 49.06 ± 44.421 at T2. In the Propofol group, the average values were 21.72 ± 10.532 at T0, 56.28 ± 32.807 at T1, and 49.00 ± 29.019 at T2.

The results of statistical tests (Mann-Whitney U test) showed no significant differences between the two groups for CK-MB at T0, T1, and T2 ($p > 0.05$). This indicates that the type of anesthesia used did not lead to significant differences in myocardial injury markers (CK-MB) at these time points.

Ejection Fraction (EF) at Preoperative and Postoperative Stages

Table 3 presents a comparison of the left ventricular ejection fraction (LVEF) before and after surgery between the Sevoflurane and Propofol groups.

Table 3. Comparison of Preoperative and Postoperative Ejection Fraction (EF) Between the Sevoflurane and Propofol Groups

Variable	Sevoflurane (N=18)	Propofol (N=18)	P-Value
EF Initial	50.01 ± 14.907	52.67 ± 13.676	0.580
EF Postop	50.72 ± 12.027	49.72 ± 12.136	0.806

In the Sevoflurane group, the average EF before surgery (EF Initial) was 50.01 ± 14.907%, and after surgery (EF Postop), it was 50.72 ± 12.027%. In the Propofol group, the EF before surgery was 52.67 ± 13.676%, and after surgery, it was 49.72 ± 12.136%. Statistical analysis (t-test for independent samples) revealed no significant differences in EF between the two groups, either preoperatively or postoperatively ($p > 0.05$). This indicates that the type of anesthesia did not lead to significant differences in left ventricular function, as measured by EF, during the postoperative period. The results of this study indicate that there were no statistically significant differences in myocardial injury markers (CK-MB) or left ventricular function (EF) between the Sevoflurane and Propofol groups in patients undergoing OPCAB surgery. Despite differences in the average age of the groups, which was found to be statistically significant, other factors such as sex, weight, height, and comorbidities did not show significant differences. These findings suggest that both anesthetic agents, sevoflurane and propofol, may have comparable effects on myocardial injury and left ventricular function during the perioperative period of OPCAB surgery. Further studies with larger sample sizes or additional biomarkers are necessary to confirm these results and explore the potential long-term effects of different anesthetic agents.

DISCUSSION

This study aimed to evaluate the myocardial protective effects of sevoflurane and propofol in patients undergoing Off-Pump Coronary Artery Bypass Grafting (OPCAB). Analysis of CK-MB levels and postoperative ejection fraction (EF) revealed no significant differences between the two groups, suggesting that sevoflurane and propofol offer equivalent myocardial protection during OPCAB surgery. These findings are consistent with those of several previous studies [6] that reported no significant differences in the myocardial protective effects of these two anesthetic agents. Although both agents have demonstrated cardioprotective properties, the results indicate their comparability in reducing myocardial injury during cardiac surgery.

Sevoflurane exerts preconditioning effects on the myocardium via mitochondrial ATP-sensitive potassium (KATP) channels. This pathway stabilizes mitochondrial membranes during ischemic events and reduces oxidative stress through the activation of protein kinase C (PKC) [6]. The cardioprotective properties of sevoflurane, particularly its ability to reduce myocardial injury in various cardiac surgical settings, are well documented. Conversely, propofol, an intravenous anesthetic, is recognized for its antioxidant property. Propofol reduces the production of reactive oxygen species (ROS) by inhibiting lipid peroxidation, thereby decreasing oxidative stress and inflammation during cardiac surgery. Studies have shown that propofol can reduce neutrophil activation and levels of pro-inflammatory cytokines, such as TNF-α and IL-6, which play a significant role in ischemia-reperfusion injury [7,8]. These anti-inflammatory effects are critical during cardiac surgeries, such as OPCAB, where myocardial injury is common due to ischemia and reperfusion. Therefore, both sevoflurane and propofol offer myocardial protection through different yet complementary mechanisms, which likely account for their comparable protective effects observed in this study.

Our findings align with previous research, including studies by Yang et al. [6] and Cromheecke et al. [8], which demonstrated that sevoflurane provides enhanced myocardial protection, particularly during surgeries involving cardiopulmonary bypass (CPB). For example, sevoflurane has been shown to reduce cardiac troponin I (cTnI) and creatine kinase-MB (CK-MB) levels in the early postoperative period [7]. However, investigations by Bignami et al. [5] and Landoni et al. [9] reported no significant differences in CK-MB and troponin levels between sevoflurane and propofol, suggesting that both agents may offer comparable myocardial protection. The variability in the results across studies may be attributed to differences in patient populations, surgical procedures, and timing of biomarker measurements [9].

The results of this study are consistent with those of Bignami et al. [6] and Hert et al. [15], who observed no significant differences in hemodynamic responses or anesthetic efficacy between sevoflurane and propofol during cardiac surgery. In our study, intraoperative hemodynamic parameters, including heart rate, mean arterial pressure, and central venous pressure, were comparable between the two groups, indicating that both the anesthetic agents provided stable hemodynamic conditions during surgery. This finding underscores the capacity of both agents to maintain adequate hemodynamic stability, which is crucial in the perioperative management of patients undergoing cardiac surgery.

Additionally, the postoperative mechanical ventilation duration, ICU stay, and length of hospital stay were similar between the two groups, further supporting the equivalence of sevoflurane and propofol in terms of postoperative recovery. These results are consistent with the findings of Jiao Xue et al. [16,18], who reported no significant differences in ICU and hospital stays between patients receiving sevoflurane and those receiving TIVA. Furthermore, none of the patients in our study experienced intraoperative awareness, highlighting the effectiveness of both anesthetic agents in maintaining an appropriate depth of anesthesia. This finding is consistent with other studies, such as those by Yang et al. [1] and Yilmaz et al. [17-20], which also reported no instances of intraoperative awareness with sevoflurane or propofol.

Although this study offers valuable insights, several limitations warrant consideration. First, the anesthesiologists were not blinded to the anesthetic technique employed in each group, potentially introducing bias in patient management. Second, the relatively small sample size may constrain the generalizability of the findings. A larger sample size could validate these results and facilitate a more robust comparison between the two anesthetic agents. Additionally, our study concentrated on OPCAB procedures, which may not fully represent the myocardial protection afforded by sevoflurane and propofol in other cardiac surgeries such as valve replacement surgeries. The variations in myocardial ischemia or injury between OPCAB and other procedures may account for the absence of a clinically significant difference in myocardial protection between the two agents. Finally, this study did not incorporate a third arm to explore the potential synergy between sevoflurane and propofol or examine the dose-dependent effects of these agents. This study suggests that sevoflurane and propofol provide comparable myocardial protection during OPCAB surgery. Both agents possess distinct mechanisms of action, with sevoflurane offering preconditioning effects and propofol providing antioxidant properties; however, they appear to offer equivalent

protection against myocardial injury during surgery. Despite these promising results, further research with a larger sample size and additional study designs, including multicenter trials, is necessary to elucidate the optimal anesthetic approach for patients undergoing cardiac surgery. Future studies should explore the potential of combining sevoflurane and propofol to enhance myocardial protection and investigate the long-term effects of these anesthetics on cardiac outcomes.

CONCLUSION

Based on the results of this study on the myocardial protective effects of inhalational anesthetic sevoflurane and total intravenous anesthetic propofol in patients undergoing OPCAB heart surgery, it can be concluded that there is no statistically significant difference in myocardial injury biomarkers (CK-MB) or cardiac function parameters (ejection fraction) between the two groups. This indicates that both sevoflurane and propofol provide equivalent myocardial protection in the context of OPCAB surgery and can be used safely and effectively for anesthetic purposes during this procedure.

DECLARATIONS

None

CONSENT FOR PUBLICATION

The Authors agree to be published in Journal of Society Medicine.

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COMPETING INTERESTS

The authors declare no conflict of interest in this case report.

AUTHORS' CONTRIBUTIONS

All authors contributed to the work, including data analysis, drafting, and review of the article. They approved the final version and were accountable for all the aspects.

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REFERENCES

1. Bojar RM. Manual of perioperative care in adult cardiac surgery. Wiley Blackwell, John Wiley & Sons, Inc.; 2021. 932 p.
2. Hausenloy DJ, Boston-Griffiths E, Yellon DM. Cardioprotection during cardiac surgery. Cardiovasc Res. 2012;94(2):253–65.
3. Heusch G. Myocardial ischemia/reperfusion: Translational pathophysiology of ischemic heart disease. Med Cell Press; 2024. p. 10–31.
4. Chiari P, Fellahi JL. Myocardial protection in cardiac surgery: a comprehensive review of current therapies and future cardioprotective strategies. Front Med. 2024;11:113.
5. Indrasutanto TF, Boom CE. Prinsip proteksi sel otot jantung dalam mesin pintas jantung paru pada prosedur pembedahan jantung terbuka. Jurnal Komplikasi Anestesi. 2017;5(1):45–52.
6. Ng CSH, Wan S. Limiting inflammatory response to cardiopulmonary bypass: pharmaceutical strategies. Curr Opin Pharmacol. 2012;12(2):155–9.

7. Jiang Y, Xu L, Liu Y, Deng B, Dong N, Chen S. Beating-heart on-pump coronary artery bypass grafting vs. off-pump coronary artery bypass grafting: A systematic review and meta-analysis. J Thorac Dis. 2021;13(8):4185–94.
8. Nego A, Sebayang O, Abdulgani HB. On-pump and off-pump coronary artery bypass grafting as an open heart surgery procedure in the management of coronary heart disease. SCRIPTA SCORE Sci Med J. 2022;4(2):113–25.
9. Khan MS, Islam MYU, Ahmed MU, Bawany FI, Khan A, Arshad MH. On-pump coronary artery bypass graft surgery versus off-pump coronary artery bypass graft surgery: a review. Glob J Health Sci. 2014;6(6):186–93.
10. Jia L, Li H, Li T. Efficacy of Sevoflurane and Propofol Anesthesia on Perioperative Adverse Cardiovascular Events and Hemodynamics in Elderly Patients With Diabetes. Clin Ther. 2024 Mar 1;46(3):246–51.
11. Yildirim V, Doganci S, Aydin A, Bolcal C, Demirkilic U, Cosar A. Cardioprotective effects of sevoflurane, isoflurane, and propofol in coronary surgery patients: a randomized controlled study. Heart Surg Forum. 2009 Feb;12(1).
12. Hensley FA, Martin DE, Gravlee GP. A practical approach to cardiac anesthesia. Wolters Kluwer Health/Lippincott Williams & Wilkins; 2013. 837 p.
13. Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, et al. Fourth Universal Definition of Myocardial Infarction (2018). J Am Coll Cardiol. 2018 Oct 30;72(18):2231–64.
14. Zaugg M, Schaub MC, Foëx P. Myocardial injury and its prevention in the perioperative setting. Br J Anaesth. 2004;93(1):21–33.
15. Scott T, Swanevelder J. Perioperative myocardial protection. Continuing Education in Anaesthesia, Critical Care and Pain. 2009;9(3):97–101.
16. Elshaer MA. Perioperative Myocardial Injury in Cardiac Surgery. Arch Biomed Eng Biotechnol. 2022 Mar 17;6(3).
17. Liu X, Liu X, Wang R, Luo H, Qin G, Wang L, et al. Circulating microRNAs indicate cardioprotection by sevoflurane inhalation in patients undergoing off-pump coronary artery bypass surgery. Exp Ther Med. 2016 Jun 1;11(6):2270–6.
18. Shekar PS. On-pump and off-pump coronary artery bypass grafting. Circulation. 2006;113(8):999–1005.
19. Puskas JD. Tips and Techniques for Multivessel OPCAB. Operative Techniques in Thoracic and Cardiovascular Surgery. 2006;11(2):78–89.
20. Kaplan JA. Essentials of cardiac anesthesia for cardiac surgery. Joel A. Kaplan, editor. Philadelphia; 2018. 327–328 p.