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Effects of sevoflurane and propofol on hemodynamics during cardiac surgery: A randomized controlled clinical trial

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Abstract

The anaesthetic support for various types of cardiac surgery such as coronary artery bypass grafting, heart valve repair or replacement is essential for success of a surgery. The planning of anaesthesia depends on the intended surgical procedure. The traditional approach is total intravenous anesthesia with propofol and inhalation with sevoflurane.

Objectives: To identify the advantages and disadvantages of propofol and sevoflurane when cardiac surgery in adults.

Material and methods: A total of 40 patients were assigned randomly into two groups to receive: in Group 1 - propofol and in Group 2 - sevoflurane. The induction to general anesthesia started with intravenous fractional administration of 1-1.5 mg/kg propofol, 5-7 μg/kg fentanyl and 1.5-2 mg/kg ketamine. Pipecuronium bromide 0.07-0.1 mg/kg was used as a myorelaxant in all patients in both groups. The anaesthesia in group P was supported with propofol 4-6 mg/kg/min intravenously by means of a perfusor as anaesthetic. In group 2, sevoflurane at a dose of 1.7-1.9 MAC was used as an anaesthetic. To maintain anaesthesia in both groups, there was a fractional administration of fentanyl at a dose of 100 μg intravenously when the heart rate and blood pressure increase, piperonium bromide in a dose of 2 mg intravenously was used for muscle relaxation.

Results: The mean arterial pressure, oxygen demand, energy expenditure, cardiac index, total peripheral resistance showed statistically significant differences between propofol and sevoflurane groups. Through the correlation analysis, the relationship between cardiac index and oxygen consumption was moderately relevant, as R was 0.4 and P>0.05.

Conclusion: When the use of sevoflurane for anesthesia, the hemodynamic parameters were stable. The oxygen consumption, energy expenditure in patients were significantly lower compared to propofol using the sevoflurane anesthesia.

Key words: hemodynamic, oxygen consumption, energy expenditure, sevoflurane, propofol, cardiac output

Introduction

Despite significant advances in anesthetic support when open heart surgeries and technological achievements in the cardiopulmonary bypass methods, the problem of intraoperative myocardial protection continues to be relevant. The anesthesia management for coronary artery bypass grafting, cardiac valve repair or replacement and ascending aorta surgery has many common principles. The planning of anaesthesia depends on the intended surgical approach to revascularisation. The surgery is usually performed via a midline sternotomy incision using cardiopulmonary bypass. The coronary artery bypass grafting without cardiopulmonary bypass can be performed either via a complete sternotomy or via a small anterior thoracotomic incision only in separate patients, and it's called minimally invasive direct coronary artery bypass grafting.

The patients who have undergone cardiac surgery are usually subject to risk of developing myocardial injury [1,2].

The incidence of perioperative myocardial infarction, the leading cause of death and complications in these

patients, can be as high as 30% of all interventions [3]. The myocardial injury is a frequent complication in patients undergoing the cardiac surgery, which could lead to delayed recovery and increase of length of hospital stay [4,5]. Several approaches are available to protect the myocardium against the injury associated with cardiac surgery [6]. A meta-analysis has shown that inhalation anaesthetics, including sevoflurane, have cardioprotective effects in patients when cardiac surgery [7]. The intravenous anaesthetics such as propofol have also been reported to have cardioprotective effects. These include a noticeable reduction in myocardial infarction size, reduced troponin release and reduction in mortality after cardiac surgery [8-10]. The increase in oxygen extraction, the oxygen consumption to oxygen delivery ratio have been shown to be associated with poor post-operative outcomes. The oxygen consumption can vary differently in the perioperative period, but it is rarely monitored directly as part of routine care [11]. TIVA has various characteristics that make it a reasonable alternative to the use of volatile substances. In Europe and elsewhere in the world, TIVA has made a cost-effective method, allowing precise titration for clinical effect. The TIVA benefits include organ protection; patient well-being; and accelerated recovery after cardiac surgery, especially when propofol is combined with remifentanil, which also contributes to cardioprotection [12]. The halogenated anaesthetics, including sevoflurane, desflurane, isoflurane, enflurane and halothane, lower the mean arterial pressure by increasing the anaesthetic gas concentration in a dose-dependent manner. The mechanism of arterial pressure reduction is related to a decrease in systemic vascular resistance, except for halothane, which decreases the systolic arterial pressure through a direct depressant effect on the myocardium and thus unchanged decreases the cardiac output [13]. Sevoflurane has less effect on haemodynamics than desflurane and isoflurane [14]. A multicentre RCT demonstrated no difference between sevoflurane anaesthesia and propofol TIVA in terms of stay in the ICU, mortality, or both in patients undergoing cardiac surgery [15]. The inhalation anaesthetics can significantly improve the haemodynamics and the inflammatory response to surgery in elderly patients [16]. The intraoperative anaesthesia and postoperative sedation with sevoflurane reduces myocardial damage and improves renal function in patients undergoing the off-pump myocardial revasculization surgery [17].

Purpose and objectives: to study the effects of sevoflurane and propofol on haemodynamics, blood oxygen transport function, metabolic cost of the body, and pharmaco-efficiency of anaesthetics when cardiac surgery in adult patients.

Material and methods

The examination and treatment data of 40 patients operated in the Cardiosurgical Department of the Medical Center Hospital of the Presidential Administration of the Republic of Kazakhstan were included in the study. All patients underwent the coronary artery bypass grafting (CABG) under cardiopulmonary bypass (CPB).

Study design: Single-centre prospective randomised controlled clinical trial.

The patients in the study subgroups were comparable at baseline, and the table shows demographic, anthropometric data, surgical volume, cardiac index, oxygen consumption, total peripheral vascular resistance (TPR), oxygen delivery and oxygen utilization (Table 1).

All patients had multivessel coronary disease. All patients had arterial hypertension of grade 3 risk 4, according to anamnesis, and the smoking history (COPD) of almost all patients numbered 30-40 years.

Table 1

Demographic, anthropometric data, surgical volume, cardiac index, oxygen consumption, oxygen delivery and oxygen utilization.

Indicator	Propofol (n=20)	Sevoflurane (n=20)
Sex		
M	13 (75%)	16 (85%)
F	7 (25%)	4 (15%)
Age, years	59,8 ± 3,1	60,5 ± 4,2
Weight, kilograms	80,5 ± 11,2	82,2 ± 13,6
Height, centimetre	167,1 ± 9,3	169,6 ± 8
Surgery duration, hour	3,9 ± 0,6	3,7 ± 0,5
AC time, minutes	70,8 ± 23,6	80,2 ± 38,2
Cardiac index, l/min/m2	2,4 ± 1,2	2,5 ± 0,7
Oxygen consumption, ml/min/m2	124,9 ± 62,8	128,9 ± 57,1
TPR, din-s-cm−5	3325,3 ± 533,5	3162,8 ± 655,0
Oxygen delivery, ml/min/m2	438,6±85,	463,1±103,2
Oxygen recovery, %	30,1±9,1	28,3±5,2
Note: P> 0.05.		

The echocardiography (echocardiography) showed the ejection fraction equal to 55-61% in all patients. 27% of all patients had also type 2 diabetes mellitus. Objectively there was no edema in extremities. Exertional dyspnea.

All patients were divided up into 2 groups: Group 1 (n=20) consisted of patients whom were administrated propofol (P) during anaesthesia. In Group 2 (n=20) inhalational anaesthesia was carried out with sevoflurane (S) as main anaesthetic.

The study was conducted in 5 stages:

1) patient's baseline values determination before anaesthesia;

2) after tracheal intubation;

3) Before the CPB;

4) after the CPB;

5) post-operative period until the patient is extubated.

At admission to the operating unit before induction into anaesthesia, haemodynamic monitoring with Nihon Kohden monitors (Japan) started. The right radial artery was catheterised for invasive systemic pressure monitoring and arterial blood sampling, after that the catheter was introduced into the central jugular vein (assisted by ultrasonic apparatus) and guided into the right atrium for mixed venous blood sampling. There was no indication for Swan-Ganz catheter insertion.

The cardiac stroke (CS) volume was determined by transthoracic echocardiography (RR=end diastolic volume-end systolic volume).There were also determined the cardiac output (CO=CS x heart rate), cardiac index (CI=CO/body surface area). Blood oxygen content was derived from formula CaO2 (arterial ABS) and CvO2 (central mixed venous ABS) = [(1.34 × Hb × SO2) + (PO2 × 0.031)] / 100, arterio-venous difference (AVD) = CaO2-CvO2. The oxygen delivery was found by formula (DO2 = CI* CaO2), oxygen consumption (VO2 = Cardiac index *AVD or VO2 = CO × (CaO2 - CvO2) ~ CB × Hb × 1,34 × (SaO2 - SvO2) / 100), oxygen utilization factor (KYO2) = VO2 / DO2 × 100 = [(CaO2 - CvO2) / CaO2] × 100.

In the second stage after tracheal intubation performed to determine VO2, energy expenditure during anaesthesia, the indirect calorimetry was used by means of a spirometer "Spirometry" (UK Oxford) which was connected to the endotracheal tube and continuously reported the oxygen demand and energy expenditure. Additionally, cardiac output and cardiac index were investigated using Fick's formula. In the third and

fourth stages of anaesthesia the same tests (cardiac index, cardiac output, oxygen intake, oxygen delivery, oxygen utilization and energy expenditure) were determined. At the last stage, to assess the pharmaco-efficiency of anaesthetics, the consumption of muscle relaxants and opioid analgesics was calculated, and the recovery and extubation time was recorded.

All patients continued their usual antihypertensive medication both before and on the day of surgery to prevent the development of withdrawal syndrome and to reduce the risk of perioperative myocardial ischaemia.

All patients in both groups were given fentanyl in a dose of 5-7 µg/kg, ketamine 1.5-2 mg/kg, and propofol 1-1.5 mg/kg intravenously fractionally. Pipecuronium bromide 0.04-0.07 mg/kg was used as muscle relaxant in all patients. To maintain anaesthesia in Group 1 P, propofol 4-6 mg/kg/hr intravenously on a perfusor (BBRAUN) was used as an anaesthetic, fentanyl 100 µg intravenously was administered fractionally to increase heart rate and blood pressure, and pipecuronium bromide 2 mg intravenously for myorelaxation. In group 2, sevoflurane was used as an anaesthetic, at a dose of 1.7-1.9 MAC. Fentanyl 100 µg intravenously was also fractionally administered to increase heart rate and blood pressure, piperonium bromide was used in a dose of 2 mg intravenously for myorelaxation. During CPB in all patients in both groups, propofol was administrated in a dose of 5-7 mg/kg/h intravenously via perfusion, analgesic regimen: fentanyl 100 µg intravenously every 30 min; myorelaxant piperonium bromide 2 mg every 40-60 min. Norepinephrine solution was administered at a dose of 0.07 µg/kg/min intravenously on a perfusor after CPB to all patients at similar dosages in both groups.

The purpose of the norepinephrine application:

1. In order to maintain mean arterial perfusion pressure (cytokine storm and vasodilation are caused by CPB).

2. For inotropic support (for reperfusion syndrome, resulting in a lower ejection fraction).

The statistical analysis was performed using SPSS package with Student's t-test for independent samples and nonparametric Mann-Whitney test. Mann-Whitney test was used only for myorelaxant consumption, as this parameter produced an abnormal distribution. Pearson correlation analysis was also performed to determine the significance of the association between cardiac index and transport, oxygen consumption and energy expenditure.

Results

The data of 40 patients operated in the Cardiosurgical Department of the Medical Center Hospital of the Presidential Administration of the Republic of Kazakhstan were included in the study. All patients underwent coronary artery bypass grafting (CABG) under cardiopulmonary bypass (CPB).

Both groups of patients were comparable in terms of baseline heart rate and mean arterial pressure (MAP). The heart rate (HR) increased from 75.8±9.4 to 89.1±8.5 bpm after tracheal intubation in the propofol group. A decrease in HR was seen after CPB and until the end of surgery of 78.1±8.4 bpm in patients treated with propofol (P=0.01). At the same time, in the sevoflurane group a significant HR decrease was noted before CPB, 64,1±10,9 bpm, and after CPB, 63,5±7,6 bpm, a slight increase to 66±4,9 bpm at the end of anesthesia was noted (P=0.01). (Figure 1). During anaesthesia, there was a significant decrease in mean arterial pressure from 93.9±9.2 to 69.4±5.8 mmHg in the propofol group (P=0.01) and to 79±8.5 mmHg in the sevoflurane group (P=0.01) (Figure 2).

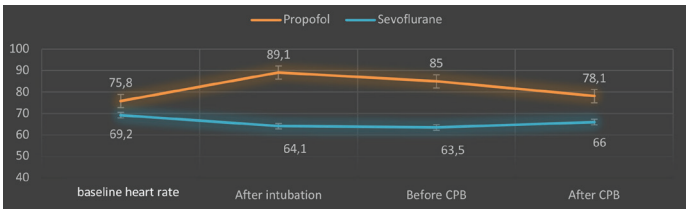

Figure 1 - Heart rate in both groups before and during anaesthesia.

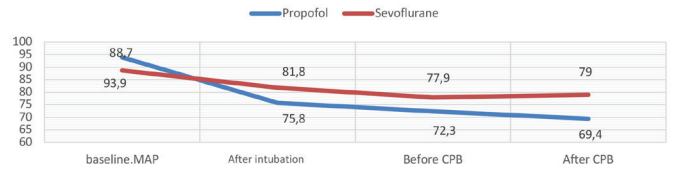

Figure 2 - Changes in mean arterial pressure before and during surgery.

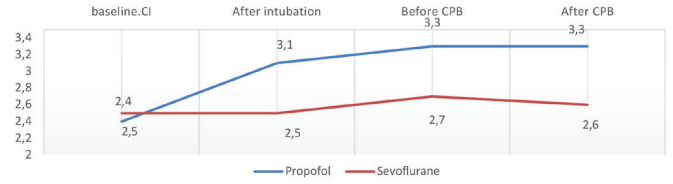

Figure 3 - Cardiac index before anaesthesia and during surgery.

Before induction into anaesthesia, mean cardiac index (CI) values were similar in both groups of patients. Propofol markedly increased CI from 2.4±1.2 l/min/m2 to 3.3±0.7 l/min/m2 during surgery (P=0.02). At the same time, there was a slight decrease in SI to 2.5±0.6 L/min/m2 in the sevoflurane group during the second phase of the study, but it increased to baseline 2.6±0.5 l/min/m2 (P=0.02) after CBP (Figure 3). Baseline total peripheral vascular resistance (TPR) values were similar. Anaesthetics reduced TPR regardless the type of anaesthesia. However, propofol significantly reduced TPR throughout the surgery from 3225.3±533.5 dyne-s-cm–5 to 1315.2±328.1 dyne-s-cm–5 after CBP (P=0.01). In the group where sevoflurane was used, the decrease in TPR was noted only after induction in anaesthesia to 2209.7±510.7 dyne-s-cm–5 (P=0.02). And then after tracheal intubation and until the end of surgery, the TPR remained practically at the same level of 2132.5±582.5 dyne-s-cm–5 (p=0.01) (Figure 4).

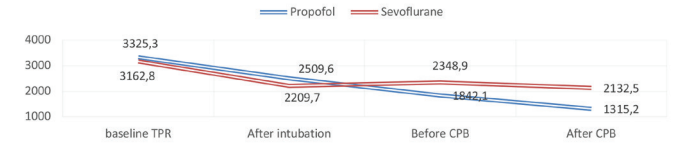

Figure 4 - Total peripheral vascular resistance before and during anaesthesia.

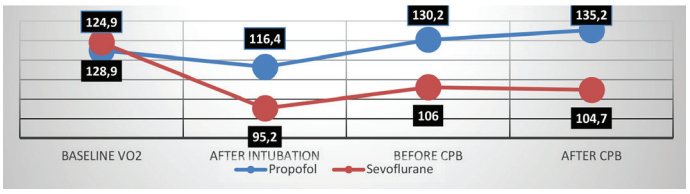

Figure 5 - Change in oxygen consumption before anaesthesia and during surgery.

Propofol anaesthesia after tracheal intubation markedly increased the oxygen delivery from 438.6±85.3 ml/min/m2 to 510.9±83 ml/min/m2 (p=0.0001). However, its decrease was noted at the pre CPB stage of 450.3±86.8 ml/min/m2 and after CPB 467.1±73.1 mL/min/m2 (p<0.01). At the same time, sevoflurane decreased DO2 throughout anaesthesia from 463.1±103.2 ml/min/m2 to 357±52.1 ml/min/m2 (p=0.01). Baseline oxygen consumption was similar in both groups. After induction into anaesthesia, both drugs dramatically reduced VO2 to 116.4±27.7 ml/min/m2 in group S and to 95.2±31.2 ml/min/m2 during propofol anaesthesia (P=0.03). However, an increase in VO2 was noted after tracheal intubation before the end of anaesthesia for propofol anaesthesia, which was 135.2±26.4 ml/min/m2 (P=0.001). In the group where sevoflurane was used, there was a non-significant increase in oxygen requirement in the third and fourth stages of the study to 106±22.3 ml/min/m2 and 104.7±13.1 ml/min/m2 after tracheal intubation (p=0.05) (Figure 5). Both groups of anaesthetics decreased the oxygen utilization during induction into anaesthesia, but after tracheal intubation there was an increase in oxygen utilization from 28.9±6.7% in group P and 21.8±2.9% in group S to 30.5±4.3% and 24±2.8% respectively (p=0.001) throughout the anaesthetic period. After tracheal intubation and after connecting the spirometry device to the intubation tube, the energy expenditure (EE) was 1444.8±174.9 kcal/d in the propofol group (P=0.003) and 1491.8±222.5 kcal/d in the sevoflurane group (P=0.004). But propofol anaesthesia after tracheal intubation prior to CPB markedly increased EE to 1842.7 ± 442.3 kcal/day, but then there was a slight decrease of energy expenditure after CPB 1592.6 ± 306.5 kcal. In S group, there was a slight increase in EE before CPB by 1524.7±285.9 kcal. At the same time, sevoflurane insignificantly decreased EE after CPB by 1430.4±199.2 kcal/day (p < 0.05) (Figure 6).

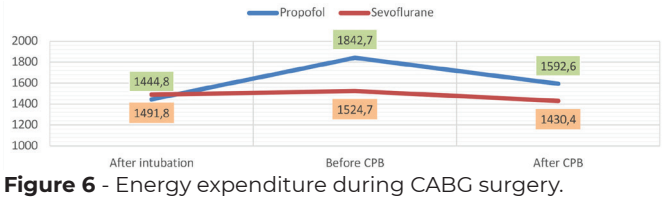

Figure 6 - Energy expenditure during CABG surgery.

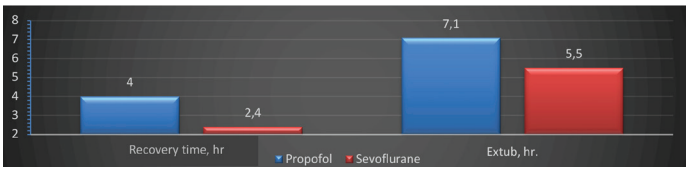

Figure 7 - Recovery and extubation times in both patient groups.

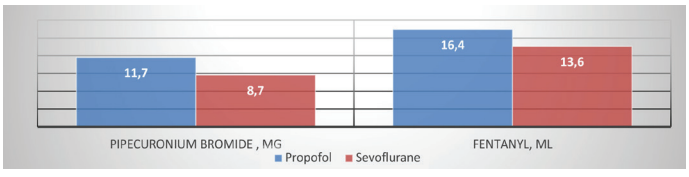

Figure 8 - Consumption of myorelaxants and narcotic analgesics in both patient groups.

The recovery time and extubation time were significantly different between the groups (Figure 7). Recovery time was equal to 4.0±1.3 hours in TIVA group and to 2.4±0.8 hours in the sevoflurane group (P=0.01). The weaning time was 7.1±1.3 h in the propofol group and 5.5±2.2 h in the sevoflurane group (P=0.01). Pipecuronium bromide 11.7±3.0 milligrams and fentanyl 8.7±1.7 ml were more required by myorelaxant and narcotic analgesics in propofol anaesthesia compared to inhaled anaesthetic 16.4±3.8 milligrams and 13.6±3.3 ml respectively (P=0.01) (Figure 8).

The correlation analysis shows that the relation between cardiac index and oxygen consumption is moderately significant, as R equals 0.4 and P>0.05. Also the correlation between cardiac index and energy expenditure is not significant, as R equals to 0.12 and P>0.05.

Discussion

The choice of optimal anaesthesia techniques for cardiac surgery is an important task. However, the TIVA and VA use during cardiac surgery is often impaired by the strength of instinct, personal experience, tradition in a given department, etc. Therefore, various authors have conducted studies on blood flow, blood oxygen transport function, energy expenditure during TIVA and inhalational anaesthesia. On the basis of the data published in Scopus, Web of Science, PubMed, Cyberleninka, Cochrane, the meta-analysis of these literature sources we found that the effect of total intravenous anesthesia with propofol and VA on haemodynamics, blood oxygen-transport function, energy expenditure during cardiac surgery is not uniform. The works of researchers have been studied [Symons J, Myles P. 2006] claiming that inhalation anesthetics, including sevoflurane, have cardioprotective action on patients during cardiac surgery. However, the authors [8-10] report that intravenous anaesthetics, such as propofol, have cardioprotective action. This includes a marked reduction in the size of myocardial infarction, a decrease in troponin release and a reduction in mortality after cardiac surgery. However, researchers [G. Landoni F. Guarracino, 2014] in a multicentre randomized trial found no difference between sevoflurane anaesthesia and propofol TIVA in terms of stay in ICU, mortality or both in patients undergoing cardiac surgery. The authors [Xinyu Chen, et al. 2020], note that intraoperative anaesthesia and postoperative sevoflurane sedation reduces myocardial damage in patients undergoing myocardial revascularisation surgery without cardiopulmonary bypass. Also, according to the author [StefanSchraag, 2015] TIVA has various characteristics that make it a reasonable alternative to the use of inhalational anaesthetics. In Europe and elsewhere in the world, TIVA has made it a cost-effective method to allow precise titration for clinical effect. Benefits of TIVA include organ protection; patient well-being; and accelerated recovery after cardiac surgery, especially when propofol is combined with remifentanil, which also contributes to cardio protection.

The present study determined changes in hemodynamics, blood oxygen transport function and body energy expenditure during sevoflurane inhalation anesthesia and propofol intravenous anesthesia in patients undergoing CABG. Our results show that rapid recovery can be achieved with both techniques, maintaining the same degree of anaesthesia during surgery in both groups. However, Sevoflurane provided better intraoperative haemodynamic stability than propofol during the CABG surgery. The mean arterial pressure was better maintained with sevoflurane compared to propofol. The heart rate differed significantly between the groups. During sternotomy when propofol was used, tachycardia occurred. The mean arterial pressure did not differ significantly between the groups. Significant increase in CI was noted in the group where propofol was used for anaesthesia only after CPB. Sevoflurane decreased the cardiac index to baseline after CPB. Both anaesthetics reduced TPR, but propofol reduced it more significantly compared to sevoflurane. The drugs decreased the oxygen uptake after tracheal intubation. However, propofol significantly increased VO2 after tracheal intubation. Sevoflurane was superior to propofol in effectiveness in reducing energy expenditure. During anaesthesia with propofol a sharp increase in energy expenditure

was noted. The patient's recovery and extubation time was longer in the propofol group compared to sevoflurane. Also, the pharmaco-economic consumption is greater in the propofol group than in the sevoflurane group.

In summary, stability of hemodynamics is very important during cardiac surgery because it allows patients to wake up quickly, regain consciousness and reduce the lung ventilator time for patients and length of their stay in the intensive care unit. In addition, the low consumption of energy during the operation has a great influence on rapid recovery of patients and rapid wound healing in the postoperative period.

Limitations of the study

This study has several limitations. The first limitation of our study lies in the fact that it was a single-center study. Multicenter studies reduce influence of the special characteristics of one single institution. The second limit of our study is the sample size, because it affects the statistical significance of the study. But we believe that randomized controlled clinical trials with a large number of patients are required.

Conclusion

Sevoflurane had the advantage over propofol with regard to better intraoperative hemodynamic stability. There was a significant difference between sevoflurane and propofol. Sevoflurane excelled in reducing oxygen demand and energy expenditure during cardiac surgery. Sevoflurane is probably a reliable alternative to propofol for cardiac surgery patients.

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