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ORIGINAL ARTICLE

Effect of anesthetic choice on perioperative inflammatory markers and postoperative pulmonary infections in cardiac surgery patients.

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ABSTRACT… Objective: To evaluate whether specific anesthetic selection significantly impacts perioperative systemic inflammatory responses and subsequent postoperative pulmonary infections in adult patients undergoing cardiac surgical procedures. **Study Design:** Cross Sectional study. **Period:** November 2025 to April 2026. **Setting:** Sahiwal Institute of Cardiology, Sahiwal. **Methods:** Total of 120 adult patients undergoing elective cardiopulmonary bypass cardiac surgery was evaluated. The patients were divided into two equal groups, allocating 60 to inhalational sevoflurane and 60 to propofol-based total intravenous anesthesia. We measured C-reactive protein, interleukin-6, tumor necrosis factor-alpha, and procalcitonin preoperatively, immediately postoperatively, and at 24 hours. Additionally pulmonary infections, mechanical ventilation duration, intensive care and hospital lengths of stay and overall mortality were monitored. **Results:** Baseline demographic and clinical characteristics were comparable. Postoperative inflammatory markers significantly elevated in both groups; however, the sevoflurane group exhibited significantly lower C-reactive protein, interleukin-6, tumor necrosis factor-alpha and procalcitonin levels compared to the propofol. Pulmonary infection rates were significantly reduced with sevoflurane administration versus propofol. Moreover, the sevoflurane group experienced significantly shortened mechanical ventilation duration, intensive care unit stays, and total hospital lengths of stay, while in-hospital mortality remained statistically equivalent between both patient study groups. **Conclusion:** Compared to propofol-based total intravenous anesthesia, sevoflurane significantly attenuates perioperative systemic inflammation, decreases pulmonary infection incidence, and accelerates overall postoperative recovery. Anesthetic selection is crucial for optimizing perioperative outcomes and minimizing postoperative clinical complications in this specific patient population.

Key words: Cardiac Surgical Procedures, C-Reactive Protein, Interleukin-6, Propofol, Sevoflurane, Tumor Necrosis Factor-alpha.

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INTRODUCTION

Cardiac surgery is one of the most complex surgical procedures performed worldwide and is often linked to a significant systemic inflammatory response caused by surgical trauma, cardiopulmonary bypass, ischemia-reperfusion injury and mechanical ventilation.[1] Despite the evolution of surgical technique and peri-operative management, postoperative complications remain to be a significant cause of extended hospital stays, rising health care expenses, and post-operative morbidity and mortality, especially pulmonary infections. Thus, an important focus of perioperative research has been to understand factors that affect the inflammatory response and postoperative infectious complications.[2]

Injury to tissues and activation of innate immune system triggers the perioperative inflammatory response, which leads to the release of many pro-inflammatory cytokines and acute-phase proteins. Common biomarkers used to measure the degree of inflammation after cardiac surgery include C-reactive protein (CRP), tumour necrosis factor alpha (TNF-α), interleukin-6 (IL-6) and procalcitonin (PCT).[3] High levels or sustained increases of these inflammatory markers have been linked to endothelial dysfunction, organ damage, impaired immune control and liability to developing postoperative infections, such as pneumonia or ventilator-associated pneumonia. Thus, measures that help to dampen the inflammatory response may enhance the recovery of the patient after surgery and clinical results.[4]

The selection of anesthetic technique has received a lot of attention in the modifiable pre-hospital factors and the anesthetic agents have immunomodulatory

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and anti-inflammatory properties in addition to their hypnotic and analgesic properties.[5] Anesthetic preconditioning with volatile anesthetics such as sevoflurane or desflurane has been found to protect against ischemia reperfusion injury, and is thought to do so by inhibiting release of inflammatory mediators and maintaining organ function.[6] In contrast, the total intravenous anesthesia (TIVA), typically employed in the form of propofol, has been shown to possess strong antioxidant and anti-inflammatory properties, through its ability to decrease oxidative stress, suppress cytokine production and regulate the activity of immune cells. These differences in pharmacology indicate that the choice of anesthetic may have an effect on postoperative inflammatory responses and infectious complications.[7]

Pulmonary infection is still one of the most frequently occurring postoperative complications after cardiac surgery. They are multifactorial, involving mechanical ventilation for prolonged periods, and the impairment of mucociliary clearance, advanced patient age, pre-existing pulmonary disease, diabetes mellitus, blood transfusions, and immune dysfunction during the peri-operative period.[8] Systemic inflammatory response due to surgery can further impair host-defence mechanisms, which also may allow bacteria to become growing points of the lower respiratory tract.[9]

Anesthetic agents can have an indirect effect on postoperative pulmonary infections because they can change inflammatory pathways and immune function; thus, choosing an anesthetic might influence the incidence or severity of postoperative pulmonary infections. Peri-operative inflammatory response has been investigated in cardiac surgical patients in a few clinical and experimental studies with relation to anesthetic technique.[10] The concentrations of inflammatory biomarkers have been shown to be lower and pulmonary outcomes to be better after using volatile anesthetics in some investigations, while others showed similar or even better anti-inflammatory effects after the use of TIVA with propofol.[11]

Monitoring PIMs in conjunction with clinically relevant PPCs could yield useful information for the improvement of anesthetic management and patient recovery. The identification of an anesthetic technique that resulted in less systemic inflammation and less pulmonary infection could form the basis for evidence -based peri-operative protocols, improve postoperative outcomes and lower the post-cardiac surgery complication load.[12]

The present study was therefore performed to assess the influence of different anaesthetic agents on perioperative inflammatory markers and development of postoperative pulmonary infections in patients undergoing cardiac surgery. They should add to existing evidence on anesthetic-induced immunomodulation and help doctors choose anesthetics that lead to better outcomes for their patients after surgery.

METHODS

The current cross-sectional study conducted in Department of Cardiac Anesthesiology and Cardiothoracic Surgery at Sahiwal Institute of Cardiology, Sahiwal for 6 months duration from November 2025 to April 2026. The study received prior approval from the Institutional Review Board (IRB/S/C-007, dated: 24-10-2025) and informed written consent of all subjects was taken. The study adhered to the ethical principles outlined in the Declaration of Helsinki. Patients were adults (age 18 years and older) with an elective cardiac surgery scheduled to be performed with cardiopulmonary bypass (CPB) such as coronary artery bypass grafting (CABG), valve replacement or combined surgery.

Patients with active infections, chronic inflammatory or autoimmune diseases, malignancy, severe hepatic dysfunction, end-stage renal disease requiring dialysis, immunosuppressive therapy, previous cardiac surgery, emergency surgery, or incomplete clinical records were excluded from the study. Using consecutive non-probability sampling, 120 patients who met the inclusion criteria were recruited and divided into two groups based on the type of anesthetic technique used during surgery.

The combination of volatile inhalational anesthesia using sevoflurane was given to 60 patients (Group A), and total intravenous anesthesia (TIVA) using propofol to 60 patients (Group B). The anesthetic

technique was decided based on the clinical judgment of the anesthesiologist who was present and the institution's practice. Demographic and clinical characteristics at baseline were recorded such as age, sex, body mass index (BMI), smoking status, diabetes mellitus, hypertension, chronic obstructive pulmonary disease (COPD), left ventricular ejection fraction (LVEF), American Society of Anesthesiologists (ASA) physical status, and type of cardiac surgery. Other intra-operative data such as surgical time, time on cardiopulmonary bypass (CPB), aortic cross clamp time, mechanical ventilation time, intra-operative blood loss, transfusion of blood and time spent in the intensive care unit (ICU) were also recorded.

Blood samples were taken from peripheral veins at three timepoints: prior to induction of anesthesia (baseline), at the end of surgery and at 24 hours after surgery. Standardized enzyme-linked immunosorbent assay (ELISA) kit methods were used to measure serum inflammatory markers, including C reactive protein (CRP), interleukin-6 (IL-6), tumor necrosis factor alpha (TNF-α) and procalcitonin (PCT), following manufacturer's instructions. Patients were followed up for the onset of pulmonary infection during the entire hospital stay. Diagnosis of postoperative pulmonary infection was established by clinical criteria (fever, purulent respiratory secretions, leukocytosis or leukopenia, new or progressive infiltrate on chest radiography, and/or microbiological culture of respiratory specimens) in accordance with established Centers for Disease Control and Prevention (CDC) criteria.

The main outcome measures were the changes in levels of the inflammatory markers in the perioperative period and the frequency of postoperative pulmonary infections. Secondary outcomes were the length of time on mechanical ventilation, the length of time in the ICU, total hospital stay, and in-hospital mortality.

Data were collected and analyzed with the help of Statistical Package for the Social Sciences (SPSS) version 26.0. For continuous variables, normality was checked by Shapiro–Wilk test, and presented as mean ± standard deviation (SD) or median with interquartile range (IQR). The continuous variables were compared between the two groups using the independent-samples t-test or the Mann–Whitney U test, while the categorical variables were compared using the Chi-square test or Fisher's exact test. To compare the level of inflammatory markers at different time points within and between groups we used repeated measures analysis of variance (ANOVA). A p-value of < 0.05 was considered significant.

RESULTS

A total of 120 patients undergoing elective cardiac surgery were included in the study. Patients were divided equally into two groups according to the anesthetic technique used: Group A (Sevoflurane anesthesia, n = 60) and Group B (Propofol-based Total Intravenous Anesthesia [TIVA], n = 60). All enrolled patients completed the study and were included in the final analysis.

TABLE-I

Baseline demographic and clinical characteristics of the study population

Variable	Sevoflurane (n=60)	Propofol TIVA (n=60)	P-Value
Age (years), Mean ± SD	59.4 ± 9.3	58.7 ± 10.1	0.682
Male, n (%)	41 (68.3)	39 (65.0)	0.701
BMI (kg/m²), Mean ± SD	27.2 ± 3.8	27.6 ± 4.1	0.571
Current Smokers, n (%)	18 (30.0)	20 (33.3)	0.695
Diabetes Mellitus, n (%)	24 (40.0)	22 (36.7)	0.708
Hypertension, n (%)	38 (63.3)	40 (66.7)	0.699
COPD, n (%)	8 (13.3)	10 (16.7)	0.602
LVEF (%), Mean ± SD	53.1 ± 7.5	52.6 ± 8.1	0.721
CABG, n (%)	39 (65.0)	37 (61.7)	0.705
Valve Surgery, n (%)	17 (28.3)	19 (31.7)	0.687
Combined Procedures, n (%)	4 (6.7)	4 (6.7)	1.000

The baseline demographic and clinical characteristics were comparable between the two groups. No statistically significant differences were observed regarding age, sex distribution, body mass index,

comorbidities, cardiac function, or type of surgical procedure ($p > 0.05$).

TABLE-II

Intraoperative characteristics

Variable	Sevoflurane (n=60)	Propofol TIVA (n=60)	p-value
Duration of Surgery (minutes)	247.5±34.2	251.9±36.7	0.497
Cardiopulmonary Bypass Time (minutes)	96.3±18.5	98.7±17.9	0.471
Aortic Cross-Clamp Time (minutes)	70.6±14.1	72.8±13.5	0.384
Blood Loss (mL)	528±122	546±118	0.417
Blood Transfusion, n (%)	17 (28.3)	20 (33.3)	0.552

There were no statistically significant differences in intraoperative variables between the two anesthetic groups, indicating comparable surgical complexity and operative management.

TABLE-III

Perioperative inflammatory marker levels

Marker	Sevoflurane	Propofol TIVA	p-value
CRP (mg/L) Baseline	5.2 ± 1.4	5.3 ± 1.5	0.781
End of Surgery	26.8 ± 6.2	31.5 ± 7.4	<0.001
24 Hours Postoperative	44.3 ± 8.5	52.6 ± 9.1	<0.001
IL-6 (pg/mL) Baseline	8.1 ± 2.3	8.4 ± 2.1	0.481
End of Surgery	67.9 ± 13.8	79.8 ± 15.2	<0.001
24 Hours Postoperative	52.4 ± 11.7	63.7 ± 12.9	<0.001
TNF-α (pg/mL) Baseline	12.4 ± 2.8	12.6 ± 3.0	0.724
End of Surgery	24.8 ± 5.6	29.7 ± 6.1	<0.001
24 Hours Postoperative	18.2 ± 4.5	22.6 ± 5.0	<0.001
Procalcitonin (ng/mL) Baseline	0.07 ± 0.03	0.08 ± 0.03	0.334
End of Surgery	0.64 ± 0.18	0.82 ± 0.21	<0.001
24 Hours Postoperative	1.28 ± 0.34	1.67 ± 0.39	<0.001

Inflammatory marker concentrations increased significantly after surgery in both groups. However, patients receiving sevoflurane anesthesia demonstrated significantly lower postoperative CRP, IL-6, TNF-α, and procalcitonin levels compared with those receiving propofol-based TIVA ($p < 0.001$).

TABLE-IV

Postoperative pulmonary infections

Outcome	Sevoflurane (n=60)	Propofol TIVA (n=60)	P-Value
Pulmonary Infection	6 (10.0%)	14 (23.3%)	0.048
Ventilator-Associated Pneumonia	3 (5.0%)	8 (13.3%)	0.113
Positive Sputum Culture	7 (11.7%)	15 (25.0%)	0.059

Postoperative pulmonary infections occurred less frequently in the sevoflurane group than in the propofol TIVA group (10.0% vs. 23.3%), reaching statistical significance ($p = 0.048$). Although ventilator-associated pneumonia and positive sputum cultures were also less common among patients receiving sevoflurane, these differences did not reach statistical significance.

TABLE-V

Secondary Postoperative Outcomes

Variable	Sevoflurane (n=60)	Propofol TIVA (n=60)	p-value
Mechanical Ventilation (hours)	10.8 ± 3.6	14.1 ± 5.2	<0.001
ICU Stay (days)	3.2 ± 1.1	4.4 ± 1.6	<0.001
Hospital Stay (days)	8.4 ± 2.1	10.2 ± 2.8	<0.001
In-Hospital Mortality	1 (1.7%)	2 (3.3%)	0.558

Patients in the sevoflurane group experienced significantly shorter durations of postoperative mechanical ventilation, intensive care unit stay, and total hospital stay compared with patients receiving propofol-based TIVA ($p < 0.001$ for all comparisons). In-hospital mortality was low in both groups, with no statistically significant difference observed.

DISCUSSION

In the present study,the effects of various anesthetic agents on perioperative inflammatory response and postoperative pulmonary infection during cardiac surgery were compared. Results showed that patients who were treated with sevoflurane-based anesthesia had significantly lower postoperative inflammatory markers, such as CRP, IL-6, TNF-α, and procalcitonin, than those treated with propofol-based total intravenous anesthesia (TIVA). Additionally, the sevoflurane group had a significantly reduced number of postoperative pulmonary infections. These patients also had a lower duration of mechanical ventilation, ICU and hospital stay, indicating that the choice of anesthetic could affect the inflammatory response and recovery.

Cardiovascular surgery with cardiopulmonary bypass leads to a massive inflammatory response, activation of leukocytes, complement, endothelial cells and cytokine cascades. Too much inflammation leads to dysfunction of organs and to a higher risk of infectious complications after surgery. As would be anticipated with surgical trauma, both groups had significant increase in inflammatory markers following surgery in the present study. Volatile anesthesia, however, appeared to have a protective effect since patients treated with sevoflurane had a significantly reduced inflammatory response.

The results of this study are similar to those of Paparella et al., who showed that volatile anesthetics offer myocardial and systemic protection, by preventing of ischemia-reperfusion injury and release of inflammatory mediators in cardiac surgery. In their meta-analysis, they recommended using volatile anesthetics to enhance outcomes after surgery over intravenous anesthetics, as they found that volatile anesthetics reduced inflammatory activation and organ injury.[13] In the same way, De Hert et al. found that sevoflurane anesthesia minimized the inflammatory response and myocardial damage in patients undergoing coronary artery bypass graft surgery. The authors said these benefits were due to anesthetic preconditioning, which preserves endothelial function and reduces inflammation by modulating signaling pathways, which helps prevent ischemia-reperfusion damage to tissues.[14]

Conzen et al reported that volatile anesthetics inhibit the production of pro-inflammatory cytokines in cardiac surgery, further corroborating the lower levels seen in the sevoflurane group after surgery. Lower production of cytokines can reduce systemic inflammatory response syndrome (SIRS), maintain immune homeostasis and reduce postoperative complications.[15] While propofol has known antioxidant and anti-inflammatory activity, the present results indicate that it may not have as great an effect on suppressing intense inflammatory response, as volatile anesthesia, during cardiopulmonary bypass. However, Kotani et al. have shown that propofol reduces activation and oxidative stress of neutrophils, but not all surgical procedures and perioperaive conditions have the same level of inflammatory inhibition.[16] The variability could be the reason why the patients who had TIVA with propofol in this study had higher levels of inflammatory markers in the postoperative period than the patients who had TIVA with sevoflurane.

A significant result of the present study was the significantly reduced incidence of postoperative pulmonary infections in the sevoflurane group. Prolonged mechanical ventilation, limited mucociliary clearance, immune dysfunction and bacterial colonization are all factors contributing to pulmonary infection as one of the most frequent sources of postoperative morbidity following cardiac surgery. Volatile anesthetics have anti-inflammatory properties that help maintain pulmonary endothelial integrity, which can help reduce susceptibility to respiratory infections. This is corroborated by the results of Uhlig et al. who found that volatile anesthetics have anti-inflammatory effects in the lungs and decrease inflammatory lung injury through modulation of the recruitment of neutrophils and production of cytokines.[17]

The present study also showed that the sevoflurane group had significantly shorter duration of mechanical ventilation, ICU and hospital stay. This has been linked to faster postoperative recovery and earlier extubation, thereby leading to improved resource utilization and decreased pulmonary complications. The findings of Jakobsen et al. were similar, with volatile anesthesia leading to quicker recovery after cardiac surgery and fewer postoperative respiratory

complications and shorter length of stay in the intensive care unit.[18] While these are promising results, some previous studies have found no clinically meaningful differences between the two anesthesia modalities (volatile and TIVA) in terms of postoperative inflammatory markers or infectious complications. Lurati Buse et al. have found that while volatile anesthetics offer measurable biological advantages, these benefits might not be consistently found in diverse patient groups, and, therefore, might not reduce mortality.[19]

The advantages of the present study are the prospective design, the use of a standardized assessment of several inflammatory markers at pre-defined perioperative time-points, and the evaluation of clinically relevant postoperative outcomes. However, some restrictions are noted. This study took place in one facility and included a relatively small sample, so the results may not be applicable to other populations. Long-term outcomes after hospital discharge were not assessed, and randomization was not carried out; this may have resulted in selection bias. Further studies with randomized controlled trials in larger numbers of patients are warranted in the future to confirm these observations and to further elucidate the immunological mechanisms by which anesthetic agents affect postoperative recovery.

In conclusion, the results of the present study showed that sevoflurane-based anesthesia provided significant benefits in terms of systemic inflammatory response, postoperative pulmonary infections, and early postoperative clinical recovery after cardiac surgery. The use of anesthetic modalities which help limit inflammatory responses may have an impact on better postoperative results and better quality of perioperative care.

CONCLUSION

In cardiac surgery patients, sevoflurane-based anesthesia led to lower concentrations of inflammatory markers perioperatively, fewer postoperative pulmonary infections and a better early postoperative recovery. The results of this study indicate that anesthetic selection could have a significant impact on perioperative outcomes. The results should be confirmed through further large-scale randomized studies.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORSHIP AND CONTRIBUTION DECLARATION	
1	**Aamir Furqan:** Conception of idea, writing.
2	**Farrukh Ahmad Sandhu:** Proof reading.
3	**Aisha Fareed:** Data analysis, writing.