Am J Transl Res 2026;18(8):6627-6639
www.ajtr.org /ISSN:1943-8141/AJTR0173475

Original Article

Effects of inhalation anesthesia with sevoflurane combined with oxygen inhalation on cerebral oxygen metabolism and cognitive function in lung cancer patients undergoing unilateral lung ventilation

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Received April 21, 2026; Accepted June 24, 2026; Epub August 15, 2026; Published August 30, 2026

Abstract: Objective: This study evaluated the effects of sevoflurane inhalation anesthesia on cerebral oxygenation and neurocognitive function during one-lung ventilation for lung cancer surgery. Methods: This retrospective study included 109 patients with lung cancer who underwent unilateral lung ventilation. Patients were divided into a propofol group (n=54) and a sevoflurane group (n=55) according to the anesthesia protocol. Hemodynamic parameters, cerebral oxygen metabolism, anesthesia recovery times, cognitive function, and pulmonary function were assessed. Results: Compared with the propofol group, the sevoflurane group had significantly lower heart rate (HR) and mean arterial pressure (MAP) at 15 minutes before surgery and immediately after surgery ($P < 0.05$). Regarding cerebral oxygenation, the sevoflurane group had significantly higher jugular venous oxygen saturation ($SjvO_2$) and regional oxygen saturation (rSO_2) than the propofol group at T1, T2, and T3 ($P < 0.05$). Analysis of cerebral oxygen metabolism indicators showed that, from T2, the sevoflurane group exhibited significantly higher Da-jvO_2 levels and lower $CERO_2$ values ($P < 0.05$) compared with the control group. No significant differences in hemoglobin concentration were observed between the two groups at any time point ($P > 0.05$). Recovery times for orientation, eye opening, and spontaneous breathing were shorter in the sevoflurane group ($P < 0.05$). MMSE scores were lower at 24 h postoperatively ($P < 0.05$), whereas all pulmonary function parameters were improved ($P < 0.05$). The proportion of postoperative POCD was higher in the sevoflurane group compared with that in the propofol group ($P < 0.05$). Conclusion: Sevoflurane inhalation anesthesia can improve cerebral oxygen metabolism, accelerate the post-anesthesia recovery process, and enhance pulmonary function in patients undergoing one-lung ventilation for lung cancer surgery compared with propofol, but it is also associated with a higher risk of postoperative cognitive dysfunction at 24 hours after surgery.

Keywords: Lung cancer, one-lung ventilation, sevoflurane, cerebral oxygen metabolism, cognitive function, pulmonary function

Introduction

Lung cancer remains one of the leading causes of cancer-related death worldwide. Its risk factors include smoking, environmental pollution, and genetic predisposition [1]. With advances in imaging-assisted screening and minimally invasive techniques, thoracoscopic radical resection has become widely adopted for lung cancer treatment [2, 3]. One-lung ventilation (OLV) is a common anesthetic technique for lung cancer surgery that provides adequate surgical field exposure; however, it may also induce physiological changes, including ventilation-perfusion mismatch, hypoxemia, and inflammatory responses [4, 5]. The above changes may affect the stability of blood supply to the brain during surgery and cause hypoxia in the brain, thus increasing the risk of post-operative cognitive dysfunction (POCD). Therefore, optimizing anesthetic protocols to reduce the adverse effects of OLV while ensuring surgical safety has become a research priority.

Cerebral oxygen metabolism is essential for central nervous system function, and its distur-

https://doi.org/10.62347/RHQW9053

bance is often associated with POCD [6]. Due to prolonged chronic hypoxia, inflammatory reactions, and metabolic demands of tumors, many lung cancer patients show varied degrees of oxygen supply-demand mismatch in the brain, and this imbalance is often worsened by single-lung ventilation [7]. Based on previous research, increased intraoperative cerebral oxygen consumption and abnormal arteriovenous oxygen content differences may reflect a state of compensatory cerebral hypermetabolism. Such alterations have been suggested to be associated with an increased risk of postoperative or long-term neurological dysfunction, although the causal relationship remains to be fully elucidated [8].

Different anesthetic techniques have varying effects on cerebral blood flow, metabolic rate and neuroinflammatory processes; therefore, they affect the extent of postoperative cognitive impairment and long-term outcomes [9-11]. Recently, inhalational anesthesia has attracted increasing attention for its potential to optimize cerebral oxygenation. Among inhalational agents, sevoflurane is widely used due to its favorable pharmacokinetic properties, including low blood-gas solubility, rapid induction and emergence, and minimal airway irritation [12, 13]. Based on the above evidence, it is believed that sevoflurane can promote neuroprotection by the following mechanisms: increasing cerebral vasodilation, reducing cerebral metabolic demand, and suppressing neuroinflammatory responses [14]. However, the exact impact on cerebral oxygen metabolism and how it affects neurocognitive function in patients undergoing one-lung ventilation for lung cancer resection has not been determined yet.

Based on the above, this study retrospectively analyzed the data of 109 patients who underwent thoracoscopic lung cancer surgery at our hospital between March 2023 and March 2025 to compare the clinical outcomes of sevoflurane inhalation anesthesia and propofol-based total intravenous anesthesia under one-lung ventilation. The study monitored changes in hemodynamics, cerebral oxygenation indices, post-operative recovery, cognitive function, and modifications to pulmonary function systematically to evaluate the clinical advantages and possible risks of sevoflurane in perioperative anesthesia management for lung cancer patients, and offer theoretical support and practical guidance.

Materials and methods

Study design and sample size estimation

This study is a retrospective, non-randomized, observational cohort study. The sample size was calculated based on the primary outcome measure, jugular bulb oxygen saturation ($SjvO_2$). Referring to the between-group difference in $SjvO_2$ reported in a previous study [15], the sample size was calculated using the following formula:

$$n = 2 \times \left[\frac{Z_{(1-\alpha/2)} + Z_{(1-\beta)}}{\delta/\sigma} \right]^2 \quad (1)$$

Where n is the required sample size per group, and $Z_{(1-\alpha/2)}$ is the critical value of the standard normal distribution corresponding to the α level; for a two-sided test with α=0.05, $Z_{(1-\alpha/2)}$ is 1.960, where $Z_{(1-\beta)}$ is the critical value of the standard normal distribution corresponding to the β level. When the power is set at 80%, $Z_{(1-\beta)}$ is 0.842, σ is the pooled standard deviation of the two groups, which is 9.06%, δ is the expected mean difference, which is 7.0%.

The calculation yielded 27 cases per group, with a total sample size of 54 cases. Considering that retrospective studies may involve incomplete data records, post-matching exclusions, and other factors, a 20% attrition or invalid data rate was preset. After adjusting the calculated sample size accordingly, the required sample size per group was 33 cases, and the total sample size needed was at least 66 cases.

Study population and clinical characteristics

The inclusion criteria are as follows: (1) scheduled for thoracoscopic radical lung cancer resection under one-lung ventilation; (2) ASA physical status class II or III; (3) expected survival > 6 months; (4) availability of complete medical records. Exclusion criteria included: (1) other serious lung diseases; (2) severe damage to the liver or kidneys; (3) severe malnutrition; (4) blood clotting disorders, low immunity, or an active systemic infection; (5) known allergic reactions to anesthetics; (6) radiation therapy,

chemotherapy or surgery in the chest within the last year.

This retrospective analysis included patients who underwent thoracic surgery for lung cancer at First People's Hospital of Linping District between March 2023 and March 2025. To minimize the selection bias and confounding bias inherent in the non-randomized retrospective design, propensity score matching was performed based on key baseline characteristics (including age, sex, American Society of Anesthesiologists Physical Status classification, tumor stage, and symptoms) to enhance comparability between the two groups. After propensity score matching, a total of 109 patients were finally included in the analysis. Based on the anesthetic regimen administered, patients were assigned to either the propofol group (n=54) or the sevoflurane group (n=55).

After propensity score matching, in the propofol group, anesthesia was maintained via continuous intravenous infusion of propofol. This cohort comprised 32 males and 22 females, with a mean age of 45.18 ± 4.32 years (range: 34-60 years), a mean body mass index (BMI) of 21.24 ± 0.37 kg/m^2 (range: 19.6-23.2 kg/m^2), and a mean disease duration of 9.03 ± 2.11 months (range: 3-14 months). According to the American Society of Anesthesiologists (ASA) physical status classification [16], 40 patients were classified as ASA II and 14 as ASA III. Histopathological evaluation revealed 20 cases of squamous cell carcinoma, 26 cases of adenocarcinoma, and 8 cases of large cell carcinoma. The sevoflurane group received inhalational anesthesia with sevoflurane and consisted of 35 males and 20 females. Their mean age was 46.24 ± 5.47 years (range: 31-60 years), mean BMI was 21.37 ± 0.44 kg/m^2 (range: 19.5-23.1 kg/m^2), and mean disease duration was 8.78 ± 2.05 months (range: 3-13 months). ASA classifications were II in 41 patients and III in 14 patients, while pathological examination identified 19 cases of squamous cell carcinoma, 28 cases of adenocarcinoma, and 8 cases of large cell carcinoma. Comparative analysis of baseline characteristics, including sex, age, BMI, disease duration, ASA status, and tumor histology, revealed no statistically significant differences between the two groups ($P > 0.05$ for all variables), thereby confirming the homogeneity of the cohorts.

This study was approved by the Ethics Committee of First People's Hospital of Linping District.

Anesthesia methods

Invasive monitoring of the radial artery was performed before induction of anesthesia, and the heart rate and respiratory status were observed via an IPM10 multi-parameter monitor (Mindray Medical, China). Upon arrival in the operating room, intravenous access was established. For induction of anesthesia, midazolam (Jiangsu Enhua Pharmaceutical Co., Ltd., China) 0.04 mg/kg, etomidate (Jiangsu Hengrui Medicine Co., Ltd., China) 0.3 mg/kg, and rocuronium (Jiangsu Hengrui Medicine Co., Ltd., China) 0.6 mg/kg were administered. A visual double-lumen bronchoscope with an appropriate inner diameter was selected for endotracheal intubation, and mechanical ventilation was performed on an Aestiva-5 7100 anesthesia machine (Datex-Ohmeda, USA). The ventilator settings were as follows: inspired oxygen concentration 50-80%; during bilateral lung ventilation, tidal volume was initially set at 8 mL/kg and subsequently reduced to 6 mL/kg after the onset of one-lung ventilation. Respiratory rate was maintained between 10 and 15 breaths/min, with a positive end-expiratory pressure (PEEP) of 5 cmH_2O applied throughout. Intraoperatively, respiratory frequency was continuously titrated to keep end-tidal carbon dioxide partial pressure ($PetCO_2$) within 26-32 mmHg. For anesthesia maintenance, patients in the propofol group received a continuous intravenous infusion of propofol at a target concentration of 3.5 μg/mL (Sichuan Guorui Pharmaceutical Co., Ltd., China), whereas those in the sevoflurane group were maintained on inhalational anesthesia with 1.85% sevoflurane (Sichuan Baili Pharmaceutical Co., Ltd., China). Doses of anesthetics were adjusted intraoperatively according to real-time hemodynamic changes. Target ventilatory parameters included a tidal volume of 6-8 mL/kg, a respiratory rate of 10-15 breaths/min, and a PEEP of 5 cmH_2O. Following the initiation of one-lung ventilation, an F14 catheter was introduced via the double-lumen bronchoscope into the non-ventilated lung and placed 2-3 cm distal to the carina, through which oxygen was continuously insufflated at a flow rate of 1-4 L/min. Maintenance anesthetics were discontin-

ued 15 minutes before the end of surgery. Immediately after surgery, neuromuscular blockade was reversed by intravenous administration of neostigmine (0.05 mg/kg, Shanghai Xinyi Jinzhu Pharmaceutical Co., Ltd.) combined with atropine (0.02 mg/kg, Anhui Changjiang Pharmaceutical Co., Ltd.). After extubation, patients were transferred to the post-anesthesia care unit for continuous observation. All surgeries were executed by the same operative team throughout the study.

Evaluation criteria

(1) Surgical parameters: For each group, the following intraoperative variables were documented: total surgical duration, duration of one-lung ventilation, and estimated blood loss.

(2) Hemodynamic measurements: The following time points were designated for monitoring HR and MAP using a multi-parameter anesthesia monitor: baseline before anesthesia induction (T0), 30 min (T1) and 60 min (T2) after one-lung ventilation initiation, 15 min before surgery ended (T3), and immediately upon surgery completion (T4). The goal of blood pressure management during surgery was to keep it within ± 20% of the pre-operative baseline (at T0 before anesthesia induction). If the MAP was below the upper or lower limit, actions were taken to reduce the depth of anesthesia, increase the speed of fluid administration, or add a vasopressor, such as phenylephrine. If the MAP exceeded the upper limit shown in the above row, either the duration of general anesthesia was extended or a blood pressure-reducing agent such as urapidine was added.

(3) Arterial blood gas analysis: At the same time, radial artery blood samples were taken at set times (T0, T1, T2, T3, T4) and immediately analyzed by the same model of blood gas analyzer. The two measured quantities were the partial pressure of oxygen in the blood (PaO_2) and the partial pressure of carbon dioxide in the blood ($PaCO_2$).

(4) Cerebral oxygen metabolism: Blood samples were simultaneously collected from the radial artery and the internal jugular bulb. A blood-gas analyzer was used to obtain values of arterial oxygen saturation (SaO_2), jugular venous oxygen saturation ($SjvO_2$) and hemoglobin (Hb). Measurement and standardization of $SjvO_2$: To obtain a representative mixed venous blood sample of the whole brain, all patients underwent ultrasound-guided retrograde placement of a central venous catheter in the internal jugular vein after anesthesia induction and before surgery. After confirming that the tip of the catheter was at the jugular bulb (at the level of the skull base) with an intraoperative chest X-ray, blood samples were collected from the radial artery and the jugular bulb. rSO_2 measurement and standardization: Using the same model of cerebral oximeter, sensors were symmetrically attached to both sides of the patient's forehead, centered approximately 2 cm above the eyebrow arch, avoiding visible superficial scalp vessels. A well-trained researcher performed the monitoring. The arterial-venous oxygen content difference ($Da\text{-}jvO_2$) and the cerebral oxygen extraction rate ($CERO_2$) were calculated according to the following formulas. $Da\text{-}jvO_2$ reflects the oxygen extraction capacity of cerebral tissue, whereas $CERO_2$ represents the proportion of oxygen extracted by the brain from arterial blood.

$$Da\text{-}jvO_2 = CaO_2 - CjvO_2 = 1.34 \times Hb \times (SaO_2 - SjvO_2) + 0.003 \times (PaO_2 - PjvO_2)$$

$$CERO_2 = (CaO_2 - CjvO_2)/CaO_2 \times 100\%$$

(5) Recovery from anesthesia: The time to regain orientation, time to open eyes, time to resume spontaneous breathing, and time to regain the swallowing reflex were recorded.

(6) Cognitive function: At 0 hour before surgery and 24 hours after surgery, the Minimum Mental State Examination (MMSE) [17] was used to evaluate the cognitive function of the patients. The dimensions of this scale were recall, orientation, language, attention, memory and calculation; a maximum score of 30 was assigned, and a score less than 24 was considered to be a sign of cognitive decline. To reduce the measurement bias of subjective outcomes in the assessment, the Mini-Mental State Examination (MMSE) was conducted by an independent researcher who did not know which group the patients belonged to. The person's cognition was assessed using the MMSE.

(7) Pulmonary function: Pulmonary function was assessed using the FGC-A+ pulmonary function analyzer (Anhui Anke Bioengineering Co., Ltd., China) at baseline (0 h preoperatively)

and 24 h postoperatively. The following parameters were recorded: forced vital capacity (FVC), maximal vital capacity (VCmax), peak expiratory flow (PEF), forced expiratory volume in one second (FEV_1), and the FEV_1/FVC ratio.

(8) Postoperative complications were identified by reviewing the patient's intraoperative anesthesia records, 24-hour postoperative monitoring records, and follow-up records, including POCD, hypoxemia, severe arrhythmias, etc. Postoperative cognitive dysfunction (POCD) was defined as a decrease of ≥ 2 points in the MMSE score at 24 hours after surgery compared to the preoperative baseline. Hypoxemia was defined as SpO_2 < 90% requiring oxygen therapy intervention. Arrhythmia refers to newly developed atrial fibrillation or supraventricular tachycardia that requires pharmacological treatment.

Data screening and processing

After data entry, logical checks and consistency tests were performed on all continuous variables, and no missing data were found for the key outcome measures. Boxplots and standardized residual analysis (with a threshold of ± 3 SD) were used to screen outliers in continuous data for hemodynamic and cerebral oxygen metabolism variables. No extreme values requiring exclusion were identified. All statistical analyses were based on valid observational data.

Statistical analysis

All statistical analyses were performed using SPSS version 27.0 (IBM Corp., USA). Continuous variables with a normal distribution are presented as the mean ± standard deviation (SD). For baseline characteristics and surgical parameters, independent samples t-tests or Mann-Whitney U tests were used for intergroup comparisons. For comparisons of repeated measures data of hemodynamic parameters (HR, MAP) and cerebral oxygen metabolism indices (Da-jvO_2, $CERO_2$) at multiple time points (T0-T4), normality and sphericity tests were first performed. If the assumptions were met, repeated-measures analysis of variance (ANOVA) was used to evaluate time effects, group effects, and time-by-group interaction effects. If the interaction effect was significant, simple effects analysis was further conducted to determine at which specific time points the two groups showed statistically significant differences. All post-hoc pairwise comparisons were adjusted using the Bonferroni method to control for Type I error. Categorical data were presented as counts and percentages (n/%), and comparisons were conducted using the chi-square test or Fisher's exact test. A two-tailed P value < 0.05 was considered statistically significant.

Results

Perioperative characteristics

Perioperative parameters, including operative time, duration of one-lung ventilation, and estimated blood loss, were similar between the two groups, with no statistically significant differences observed (P > 0.05). These data are summarized in **Table 1**.

Hemodynamic profiles

Analysis of hemodynamic variables at predefined time points. The results showed that both HR and MAP had significant main effects of time (HR: F=16.891, P < 0.001; MAP: F= 25.820, P < 0.001) and significant group × time interaction effects (HR: F=3.012, P=0.019; MAP: F=2.491, P=0.045), while the main effects of group were not significant (HR: F=0.123, P=0.727; MAP: F=0.852, P=0.358). The results of simple effect analysis showed that there were no significant between-group differences in heart rate (HR) at T0, T1, or T2, nor in mean arterial pressure (MAP) at T0, T1, T2, or T3 (all P > 0.05). However, compared with the propofol group, patients in the sevoflurane group demonstrated significantly lower HR at T3 and T4 (P < 0.05) and significantly lower MAP at T4 (P < 0.05). **Figure 1** summarizes the obtained results.

Arterial blood gas analysis

The comparison of PaO_2 and $PaCO_2$ between the two groups at different time points is shown in **Figure 2**. PaO_2 showed a highly significant main effect of time (F=35.500, P < 0.001), while the main effect of group (F= 0.750, P=0.388) and the group × time interaction (F=1.200, P=0.310) were not significant. Further between-group comparisons showed that PaO_2 increased in both groups during one-

Table 1. Comparison of operative time, single-lung ventilation time, and intraoperative blood loss between the two groups of patients

Indicators	Propofol group (n=54)	Sevoflurane group (n=55)	*T*-value	*P*-value
Surgery time (min)	180.25±15.17	178.30±15.44	-0.149	0.553
Unilateral ventilation time (min)	170.10±11.36	169.73±12.09	-0.223	0.429
Intraoperative blood loss (mL)	161.52±18.04	165.03±17.75	0.162	0.514

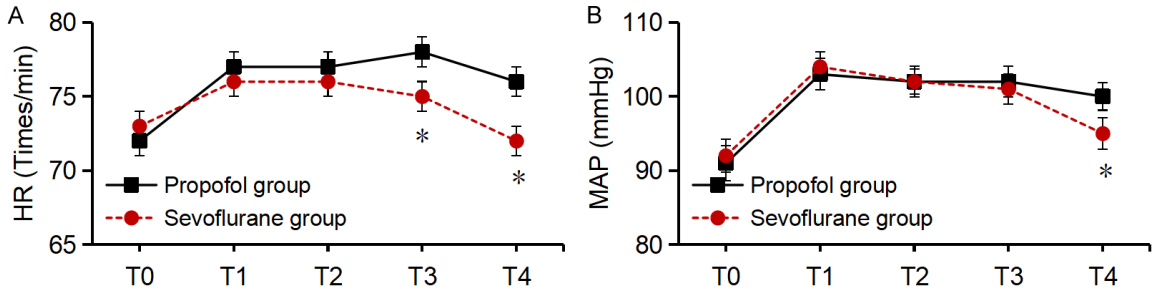

Figure 1. Comparison of hemodynamic parameter trends between the two patient groups. A: Heart rate (HR) trend; B: Mean arterial pressure (MAP) trend. * indicates a significant difference compared with the propofol group, $P < 0.05$.

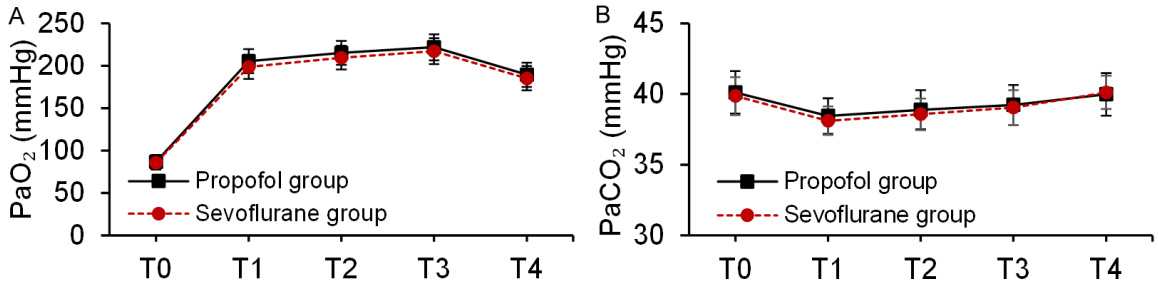

Figure 2. Comparison of arterial blood gas parameter trends between the two groups. A: Partial pressure of oxygen in the blood (PaO_2); B: Partial pressure of carbon dioxide in the blood ($PaCO_2$).

lung ventilation (T1, T2, T3), but there were no significant differences between the two groups at any time point (all $P > 0.05$). There were no statistically significant differences in $PaCO_2$ between the two groups at any intraoperative time point (T1-T4) (all $P > 0.05$), and the values remained stable within the clinical target range of 35-45 mmHg.

Comparison of cerebral oxygen metabolism parameters and hemoglobin indicators between the two groups

This study assessed cerebral oxygenation status by monitoring jugular venous oxygen saturation ($SjvO_2$) and regional cerebral oxygen saturation (rSO_2). Both $SjvO_2$ and rSO_2 showed significant main effects of time ($SjvO_2$: F=12.435, $P < 0.001$; rSO_2: F=18.264, $P < 0.001$), main effects of group ($SjvO_2$: F=18.162, $P < 0.001$; rSO_2: F=14.752, $P < 0.001$), and group × time interactions ($SjvO_2$: F=5.983, P=0.003; rSO_2: F=4.127, P=0.019). The data showed no statistically significant differences in $SjvO_2$ and rSO_2 between the two groups at T0 ($P > 0.05$). There was a significant group × time interaction effect in the model ($P < 0.05$). Post hoc tests with Bonferroni correction indicated that, at T1, T2, and T3, the $SjvO_2$ values in the sevoflurane group (71.89 ± 4.67%, 70.45 ± 4.52%, and 69.12 ± 4.38%, respectively) were significantly higher than those in the propofol group (65.23 ± 4.85%, 64.78 ± 4.91%, and 66.45 ± 4.60%, respectively), with t-values of 7.425, 6.482, and 3.162, respectively, and all *P*-values < 0.05. The trend in rSO_2 was similar, with the

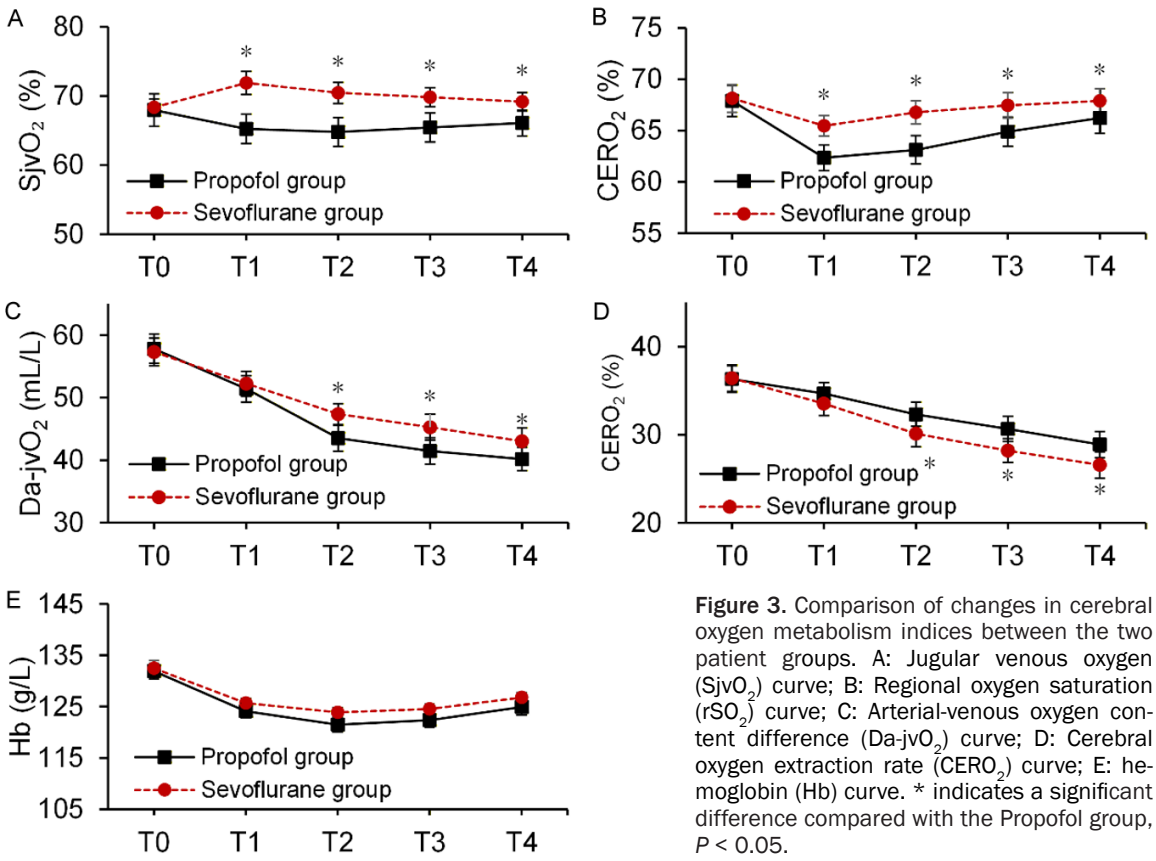

Figure 3. Comparison of changes in cerebral oxygen metabolism indices between the two patient groups. A: Jugular venous oxygen ($SjvO_2$) curve; B: Regional oxygen saturation (rSO_2) curve; C: Arterial-venous oxygen content difference ($Da\text{-}jvO_2$) curve; D: Cerebral oxygen extraction rate ($CERO_2$) curve; E: hemoglobin (Hb) curve. * indicates a significant difference compared with the Propofol group, $P < 0.05$.

sevoflurane group showing significantly higher values at T1-T3 (65.45 ± 5.01%, 66.78 ± 5.12%, and 67.45 ± 5.23%, respectively) compared to the propofol group (62.34 ± 5.89%, 63.12 ± 5.76%, and 64.89 ± 5.65%, respectively), all with *P*-values < 0.05. Both $Da\text{-}jvO_2$ and $CERO_2$ showed significant main effects of time ($Da\text{-}jvO_2$: F=22.156, $P < 0.001$; $CERO_2$: F=20.873, $P < 0.001$), main effects of group ($Da\text{-}jvO_2$: F=16.324, $P < 0.001$; $CERO_2$: F=19.857, $P < 0.001$), and group × time interactions ($Da\text{-}jvO_2$: F=7.452, $P < 0.001$; $CERO_2$: F=8.912, $P < 0.001$). Evaluation of cerebral oxygenation indices revealed no statistically significant intergroup differences in $Da\text{-}jvO_2$ or $CERO_2$ at T0 and T1 ($P > 0.05$). At subsequent time points, the sevoflurane group exhibited significantly higher $Da\text{-}jvO_2$ values at T2, T3, and T4 ($P < 0.05$), accompanied by significantly lower $CERO_2$ values at the same time points ($P < 0.05$) relative to the propofol group, as shown in **Figure 3**.

To exclude the influence of differences in blood oxygen-carrying capacity on cerebral oxygen metabolism, this study simultaneously compared arterial hemoglobin concentration (Hb). The main effect of time (F=1.245, *P*=0.294), the main effect of group (F=0.712, *P*=0.387), and the group × time interaction (F=0.891, *P*=0.471) for Hb were all not significant. The results showed no statistically significant difference in Hb concentration between the two groups at any time point ($P > 0.05$). At T1, the Hb concentration in the sevoflurane group was 125.67 ± 9.45 g/L, while that in the propofol group was 124.12 ± 10.34 g/L (t=0.829, *P*=0.409). At T4, the values were 126.78 ± 9.67 g/L and 124.90 ± 10.23 g/L, respectively (t=1.011, *P*=0.314). **Figure 3** summarizes the obtained results.

Comparison of postoperative recovery parameters

No significant difference was observed between the two anesthetic groups in the duration required for return of the swallowing reflex ($P > 0.05$). By comparison, the sevoflurane group achieved significantly shorter recovery times for orientation, eye opening, and sponta-

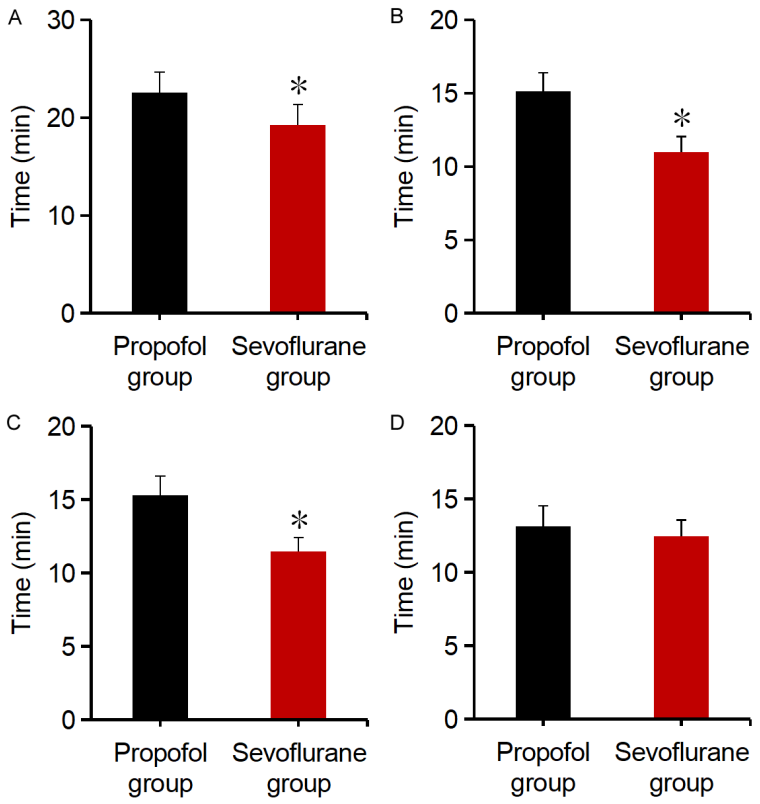

Figure 4. Comparison of recovery parameters between the two groups of patients. A: Time to regain orientation; B: Time to open eyes; C: Time to resume spontaneous breathing; D: Time to regain the swallowing reflex. * indicates a significant difference compared with the propofol group, $P < 0.05$.

Table 2. Comparison of MMSE scores before and after surgery between the two groups of patients

Indicators	Propofol group (n=54)	Sevoflurane group (n=55)	*P*-value
0 h	28.29±0.38	28.33±0.41	0.752
24 h	26.51±0.23	23.21±0.26	< 0.001
P-value	0.019	< 0.001	

neous breathing ($P > 0.05$). **Figure 4** summarizes the obtained results.

Comparison of cognitive function between the two groups

The change trends of MMSE scores within 24 hours were significantly different between the two groups. There was a significant group × time interaction (F=13.550, $P < 0.001$), a main effect of time (F=25.374, $P < 0.001$), and a main effect of group (F=15.892, $P < 0.001$) for MMSE scores. Analysis of MMSE scores revealed comparable cognitive performance between the sevoflurane and propofol groups immediately after surgery (0 h; $P < 0.05$). By 24 h postoperatively, both groups showed a marked reduction in MMSE scores from their respective 0 h levels ($P < 0.05$). Notably, the sevoflurane group had significantly lower MMSE scores at 24 h than the propofol group ($P < 0.05$). A graphical representation of these findings is provided in **Table 2**.

Comparison of pulmonary function parameters between the two groups

VCmax, FVC, FEV_1, FEV_1/FVC, and PEF all showed significant main effects of time ($P < 0.001$), main effects of group ($P < 0.05$), and group × time interactions ($P < 0.001$). Comparing the differences in pulmonary function parameters before and after surgery between the two groups, the results showed that there were no statistically significant differences in VCmax, FVC, FEV_1, FEV_1/FVC, and PEF at 0 h in both groups ($P > 0.05$). Analysis of pulmonary function indices showed that at 24 h after surgery, both groups had significantly elevated VCmax, FVC, FEV_1, FEV_1/FVC, and PEF relative to their baseline (0 h) measurements ($P < 0.05$). Moreover, at the 24 h time point, the sevoflurane group exhibited significantly elevated levels across all assessed parameters compared to the propofol group ($P < 0.05$). **Figure 5** summarizes the obtained results.

Comparison of postoperative complications between the two groups

The incidence of major postoperative complications in the two groups is shown in **Table 3**. The incidence of postoperative POCD was significantly higher in the sevoflurane group than that in the propofol group ($P < 0.05$). Within 24 hours after surgery, the proportion of hypoxemia and serious arrhythmias was slightly high-

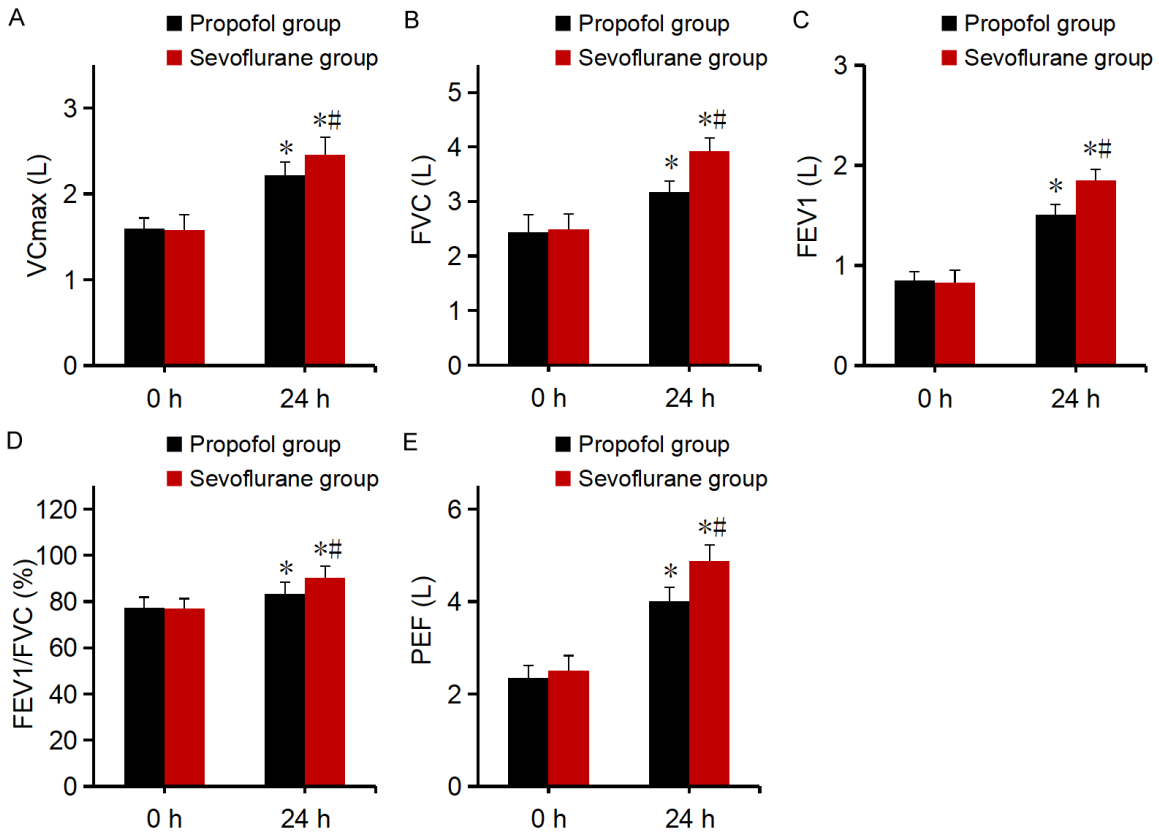

Figure 5. Comparison of pulmonary function parameters between the two patient groups. A: Maximal vital capacity (VCmax); B: Forced vital capacity (FVC); C: Forced expiratory volume in one second (FEV_1); D: Forced expiratory volume in one second (FEV_1)/forced vital capacity (FVC); E: Peak expiratory flow (PEF). * indicates a significant difference compared to 0 h within the same group, $P < 0.05$; # indicates a significant difference compared to the propofol group, $P < 0.05$.

Table 3. Comparison of postoperative complication rates between the two groups

Complication	Propofol group (n=54)	Sevoflurane group (n=55)	χ^2 value	*P* value
Postoperative POCD	5 (9.3%)	13 (23.6%)	4.214	0.040
Hypoxemia	3 (5.6%)	7 (12.7%)	1.745	0.186
Significant arrhythmia	2 (3.7%)	5 (9.1%)	1.385	0.239

Note: POCD: postoperative cognitive dysfunction.

er in the sevoflurane group compared to the propofol group, but this did not meet the threshold for statistical significance ($P > 0.05$).

Discussion

The choice of anesthetic protocol affects the safety and outcomes of patients undergoing one-lung ventilation during thoracic oncologic resection [18]. Anesthetic agents exert multifaceted effects on the nervous, cardiovascular, and pulmonary systems, thereby modulating intraoperative stress responses, oxygen consumption, and postoperative organ recovery [19, 20]. Although more studies have been carried out in recent years to compare inhalation and intravenous anesthesia, their particular advantages under different physiological conditions in the setting of single-lung ventilation for patients with lung cancer are not well-known. Our findings indicate that sevoflurane maintains hemodynamic stability, enhances cerebral oxygenation, and promotes postoperative recovery compared with propofol. The above results will help reduce the risk of mor-

bidity in the perioperative period and improve overall health after surgery.

Compared with the propofol group, the sevoflurane group had lower heart rates and mean arterial pressure at the end of surgery and in the first hours after surgery. Therefore, sevoflurane-based anesthesia may reduce the activity of the sympathetic nervous system and lower the amount of the stress response. Sevoflurane may reduce the release of catecholamines, decrease peripheral vascular resistance, and weaken the force of heart muscle contraction; thus, it is expected to have little impact on cardiovascular functions [21]. Sevoflurane has minimal effect on baroreflex function and may help stabilize blood pressure fluctuations during anesthesia [22]. In addition, people under sevoflurane had a shorter time to regain consciousness, open their eyes, and spontaneously breathe after surgery. The main reason is that it has a low blood-gas partition coefficient and is not accumulated in the body; thus, upon stopping the administration, it can be quickly eliminated from the lungs to speed up recovery. Sevoflurane has a relatively weak depression effect on the respiratory center and can help people breathe more quickly; thus, it is often chosen to reduce the risk of postoperative respiratory complications [23, 24].

Cerebral oxygen metabolism is a general indicator of perioperative brain functional status in patients with lung cancer [25]. Da-jvO_2 reflects cerebral oxygen consumption. An elevated Da-jvO_2 generally indicates that, when cerebral oxygen supply is relatively insufficient or cerebral metabolic demand is increased, the brain tissue compensates by increasing the oxygen extraction rate, suggesting a potential risk of cerebral oxygen supply-demand imbalance [26]. CERO2 is the ratio of oxygen extracted from the brain tissue in arterial blood; an increase in CERO2 suggests that cerebral oxygen utilization has improved and there is an imbalance between supply and demand [27]. Together, the two indicators can help us determine the state of cerebral oxygen consumption. According to the results of this study, in the sevoflurane group, Da-jvO_2 increased and CERO_2 decreased at times T2 to T4. Therefore, it can be concluded that cerebral tissue oxygen supply is enhanced and oxygen utilization efficiency is improved in the presence of sevoflurane inhalation anesthesia. Sevoflurane may increase blood flow to the brain through cerebral vasodilation and thus improve the amount of oxygen supplied to the brain [28]. Sevoflurane can also reduce the metabolic rate of the brain, decrease oxygen consumption, and thus lower oxygen uptake in the brain [29, 30]. Nevertheless, at 24 hours after surgery, the MMSE score for the sevoflurane group was relatively low compared with that of the propofol group; that is to say, early cognitive decline appeared sooner. Therefore, it can be assumed that sevoflurane inhalation anesthesia may have a particular inhibitory effect on cognitive function in the short term. It may be that the residual effect of inhalational anesthesia on the neurotransmitter system is prolonged, or it could also be due to differences among individuals and changes in the depth of anesthesia. Therefore, in the actual work of clinical practice, the benefits of neuroprotection need to be considered along with the risk of cognitive impairment.

Recovery of respiratory function is a primary objective in evaluating the effectiveness of thoracic oncologic surgery [31]. According to the examination of our results, in 24 hours after surgery, the sevoflurane group had significantly better indicators for VCmax, FVC, FEV_1, FEV_1/FVC, and PEF than the propofol group. Therefore, it is expected that sevoflurane may induce bronchodilation and thus reduce pulmonary impedance [32-34]. It may also reduce inflammation and harm to the lung parenchyma [35]. Sevoflurane can maintain the good elasticity of the lungs and ventilation-perfusion ratio to help the lungs recover after surgery [36, 37]. Sevoflurane has the function of improving spontaneous respiration restoration and is also good for the pulmonary condition after surgery.

Several limitations of the research should be acknowledged. Propensity score matching (PSM) and multivariable regression were applied in the initial analysis; however, these methods remain inherently retrospective and observational, and therefore cannot fully eliminate selection bias and confounding factors. Due to the single-institution setting and a small number of subjects (n=109), the results may not be representative of the general public. Third, the evaluation of mental health was based only

on the MMSE score 24 hours after surgery, and there were no long-term follow-up records for several days or weeks after the operation. Therefore, the long-term effects of sevoflurane on cognitive function have not been determined yet, and only the initial postoperative period can be observed. Fourth, the MMSE index is affected by the background of study for old people; therefore, we were unable to collect or standardize the number of study years systematically. Although neither group had large differences in pre-operative cognition, it is still a confounding factor that needs to be addressed in the next study. Fifth, the identification of POCD was based on a single MMSE tool and changes in scores at the 24-hour mark. More neuropsychological tests and several rounds of evaluation would be employed to get more reliable results. Finally, there is no information on inflammatory cytokines and neurochemical markers, so we cannot understand the basic mechanisms better. More research is needed in some areas to carry out large-scale, prospective randomized trials, and molecular biomarkers should also be added to help us better understand how long after sevoflurane exposure the nervous system and recovery after surgery are affected.

Conclusion

In patients undergoing one-lung ventilation for lung cancer surgery, sevoflurane inhalation anesthesia improves intraoperative cerebral oxygen metabolism indicators, accelerates anesthetic recovery, and enhances early postoperative pulmonary function. However, sevoflurane was associated with decreased MMSE scores at 24 hours postoperatively and a higher incidence of POCD. Due to the lack of long-term follow-up data, it remains uncertain whether the effects of sevoflurane on cognitive function are transient or sustained. It is recommended that clinical applications take into account its potential impact on early cognitive function, and further prospective studies incorporating long-term, multi-dimensional neuropsychological assessments are needed for validation.

Disclosure of conflict of interest

None.

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