Jugular Bulb Venous Oxygen Saturation During One-Lung Ventilation Under Sevoflurane- or Propofol-Based Anesthesia for Lung Surgery

Masato Iwata, MD,* Satoki Inoue, MD,* Masahiko Kawaguchi, MD,* Makoto Takahama, MD,† Takashi Tojo, MD,† Shigeki Taniguchi, MD,† and Hitoshi Furuya, MD*

Objective: **During one-lung ventilation (OLV), systemic oxygenation can be compromised. In such a scenario, if anesthetic techniques were used that adversely affected cerebral oxygen balance, the risk for impaired cerebral oxygen balance may be increased. In this study, jugular bulb venous oxygen saturation (SjO_2) during OLV under sevoflurane- or propofol-based anesthesia for lung surgery was investigated.**

Design: **Prospective clinical study.**

Setting: **University hospital.**

Participants: **Fifty-two adult patients scheduled for elective thoracic procedures in the lateral position.**

Interventions: **Patients were randomly allocated to either the sevoflurane or propofol group (n = 26). General anesthesia was maintained with sevoflurane or propofol combined with epidural anesthesia.**

Measurements and Main Results: **Arterial and jugular bulb blood samples were measured before OLV, 15 minutes after OLV, 30 minutes after OLV, and 15 minutes after the termination of OLV. SjO_2 values in both sevoflurane and propofol groups significantly declined during OLV ($p < 0.05$). SjO_2 values in the sevoflurane group were higher than in the propofol group, although SaO_2 values were similar ($p < 0.05$). Regarding the incidence of SjO_2 <50% (cerebral oxygen desaturation), there were significant differences between the sevoflurane group and the propofol group during both normally ventilated conditions (0% *v* 7.7%, $p < 0.05$, relative risk [RR]: not applicable) and OLV (1.9% *v* 26.9%, $p < 0.05$, RR = 14; 95% confidence interval [CI] 1.91-103). Significant increase in the incidence of SjO_2 <50% during OLV was also observed only in the propofol group (from 7.7% to 26.9%, $p < 0.05$, RR = 3.5; 95% CI 1.29-12.4).**

Conclusion: **Cerebral oxygen desaturation was more frequently detected during OLV under propofol- versus sevoflurane-based anesthesia. Cerebral oxygen balance during OLV for lung surgery was less impaired under sevoflurane-based anesthesia compared with propofol; however, the clinical outcome or implications for cognitive function need to be determined.**

KEY WORDS: jugular bulb venous oxygen saturation, one-lung ventilation, sevoflurane, propofol, lung surgery

SEVOFLURANE AND PROPOFOL have been widely used as anesthetic agents during one-lung ventilation (OLV) for lung surgery.[1,2] The effects of these agents on hypoxic pulmonary shunting during OLV have been shown to be limited, although it has been reported that volatile anesthetics inhibit hypoxic pulmonary vasoconstriction.[2,3] Regarding the neurologic effects of these anesthetics, cerebral blood flow (CBF) may vary, although both drugs reduce the cerebral metabolic rate for oxygen ($CMRO_2$). It has been shown that sevoflurane decreased, maintained, or increased CBF, whereas propofol reduced CBF.[4-14] Several studies suggested that during propofol anesthesia, the reduction of CBF was larger than the reduction of $CMRO_2$, resulting in a decrease of the $CBF/CMRO_2$ ratio.[10-12] Consequently, it has been recognized that cerebral oxygen balance during propofol-based anesthesia can be impaired compared with sevoflurane-based anesthesia.

The ventilatory management is often difficult during OLV, and systemic oxygenation can be compromised. In such a scenario, if the anesthetic technique used adversely affected the cerebral oxygen balance, the risk of an impaired cerebral oxygen balance may be increased. Therefore, it is important to determine the cerebral oxygen balance during OLV. In addition, it is also warranted to determine the effect of anesthetic choice on the cerebral oxygen balance during OLV.

Jugular bulb venous oxygen saturation (SjO_2) has been used to indirectly assess global cerebral oxygen use.[15-19] Therefore, the current study was conducted to investigate whether SjO_2 decreased when using sevoflurane- and propofol-based anesthetics for OLV and whether the incidence of desaturation (SjO_2 <50%, indicative of poor cerebral oxygen balance[18,19]) increased.

METHODS

After institutional approval and informed consent, 52 patients scheduled for elective thoracic procedures in the lateral position were enrolled (wedge resection with thoracoscopic surgery = 7, lobectomy with thoracotomy = 37, and wedge resection with thoracotomy = 8). Exclusion criteria included renal insufficiency (creatinine >1.5 mg/dL), liver dysfunction (aspartate aminotransferase >40 U/dL), cerebral infarction, documented coagulopathy, or coronary or vascular disease. No patient had a history of myocardial infarction or arrhythmia before the operation.

All patients were premedicated with roxatidine (H2 blocker), 75 mg orally, 2 hours preoperatively. Thereafter, the 52 patients were randomly allocated to the propofol or the sevoflurane group by using computer-generated random numbers. Before the induction of anesthesia, an epidural catheter was inserted at the thoracic 6-7, 7-8, or 8-9 interspaces. To obtain a bispectral index (BIS) score, the electroencephalographic signal was recorded by using the Aspect A-2000 electroencephalogram monitor (BIS version 3.4; Aspect Medical Systems, Newton, MA).

General anesthesia was induced with propofol, 1.5 to 2.5 mg/kg, and fentanyl, 1 to 2 μg/kg, in the sevoflurane group and with target-controlled infusion (TCI) doses of propofol and fentanyl, 1 to 2 μg/kg, in the propofol group. Tracheal intubation was facilitated with vecuronium, 0.15 mg/kg. A left-sided double-lumen endotracheal tube (Broncho-Cath; Tyco Healthcare, Argyle, Mansfield, MA) was placed for OLV, and the correct position was confirmed by auscultation and fiberoptic bronchoscopy. Anesthesia was maintained with 50% oxygen provided with an oxygen-air mixture, BIS-oriented TCI of propofol in

*From the Departments of *Anesthesiology and †Thoracic and Cardiovascular Surgery, Nara Medical University, Nara, Japan.*

Address reprint requests to Satoki Inoue, MD, Department of Anesthesiology, Nara Medical University, 840 Shijo-cho, Kashihara, Nara 634-8522, Japan. E-mail: senioue@naramed-u.ac.jp

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Table 1. Demographic Variables

	Propofol (n = 26)	Sevoflurane (n = 26)
Age (y)	61 ± 9	63 ± 8
Sex (male/female)	16/10	17/9
Weight (kg)	59 ± 13	58 ± 8
Height (cm)	160 ± 8	160 ± 7
Anesthesia time (min)	304 ± 110	292 ± 74
Operation time (min)	202 ± 110	191 ± 73

NOTE. Data are expressed as mean ± standard deviation (except for sex).

the propofol group or inhaled sevoflurane in the sevoflurane group, and an epidural bolus injection of 6 to 10 mL of 0.375% ropivacaine followed by a continuous infusion of 4 to 8 mL/h. The target blood concentration of propofol and expired concentration of sevoflurane were adjusted to keep a BIS score of 45 to 55. Nitrous oxide was not used. Routine monitoring included an electrocardiogram, radial arterial catheter, noninvasive blood pressure cuff, pulse oximetry, and capnogram. Diprifusor TCI (Zeneca Pharmaceuticals, Macclesfield, UK) was used as the TCI system in the propofol group. The expired concentration of sevoflurane was recorded by a multigas monitor (AG-920R multi-gas unit; Nihon Kohden, Tokyo, Japan) in the sevoflurane group. Systolic blood pressure was maintained within 20% of the preoperative value. When hypotension or hypertension was observed, a bolus of ephedrine or nicardipine was used. Rectal temperature was maintained at 36° to 37°C with a heating blanket.

OLV was started just before the pleura was opened. After the endobronchial cuff was inflated, the corresponding limb of the connector of the double-lumen tube was opened to the atmosphere and suctioned through a fiberoptic bronchoscope to facilitate and expedite lung collapse. The inspiratory tidal volume was set at 10 mL/kg, and the respiratory rate was adjusted to maintain $PaCO_2$ at around 40 mmHg. A ratio of 1:2 was applied for the ratio of inspiratory-to-expiratory time. The tidal volume was decreased if peak airway pressure exceeded 25 cmH_2O. OLV was terminated just after the chest was closed. The surgical lung was suctioned and inflated, and then the endobronchial cuff was deflated. All patients were extubated in the operating room at the conclusion of surgery.

To obtain blood samples from the right jugular bulb intermittently, a 19-G long elastic catheter (EVTL-MR 19 G 150 mm RB; Hakko, Tokyo, Japan) was inserted into the right jugular bulb (performed by MI). The catheter position was verified radiologically with anteroposterior skull projections in the operating room. By using a commercial blood gas analyzer (ABL 700 analyzer; Radiometer, Copenhagen, Denmark), the following variables were measured within 3 minutes after the simultaneous sampling of arterial and jugular bulb venous blood: $PaCO_2$ and arterial and jugular bulb venous partial pressure of carbon dioxide; and $PaCO_2$ and arterial and jugular bulb venous partial pressure of oxygen (PjO_2), pH, hemoglobin (Hb), SaO_2, and SjO_2. The values for pH, PaO_2, and $PaCO_2$ were not corrected for temperature. Samples of jugular bulb blood were drawn at a rate of approximately 2 mL/min to reduce the chance of extracerebral blood contamination. To estimate cerebral oxygen balance, the arteriojugular venous oxygen content difference ($AJDO_2$) and cerebral oxygen extraction ratio (COER) were calculated by using the following equations:

$$CaO_2 = (SaO_2 \times Hb \times 1.39) + 0.0031 \times PaO_2$$

$$CjO_2 = (SjO_2 \times Hb \times 1.39) + 0.0031 \times PjO_2$$

$$AJDO_2 = CaO_2 - CjO_2$$

$$COER = 100 \times AJDO_2/CaO_2$$

where CaO_2 and CjO_2 are the arterial and jugular bulb venous oxygen contents.

Hemodynamic variables, SpO_2, and arterial and jugular bulb venous blood gas analysis were obtained at the following points: time 1, before the initiation of OLV; time 2, 15 minutes after the determination of OLV settings; time 3, 30 minutes after the determination of OLV settings; and time 4, 15 minutes after the termination of OLV. All measurements were performed in the lateral position.

A power analysis was based on the following procedure. It was assumed that the incidence of SjO_2 <50%, which is indicative of poor cerebral oxygen balance[8,19] during OLV, would be 30% for propofol, and it was estimated that the incidence of SjO_2 <50% for sevoflurane would be one third of the value for propofol.[14] Based on the formula for normal distribution and assuming a type I error protection of 0.05 and a power of 0.95, 52 patients were required for the study.

To compare the demographic variables of patients between the 2 groups, an unpaired *t* test, chi-square test, or Fisher exact test was used. If possible, the relative risk (RR) and 95% confident interval (CI) were also calculated. Comparisons of measured variables such as hemodynamic variables, SpO_2, and blood gas analyses were performed by using 2-way analysis of variance with repeated measures followed by an unpaired *t* test. The data are expressed as mean. Differences were considered significant when p was <0.05.

RESULTS

Demographic variables are shown in Table 1. There were no significant differences in demographic variables between the 2 groups. Ten patients in the sevoflurane group and 11 patients in the propofol group were given 5 cmH_2O of positive end-expiratory pressure to the dependent lung or continuous positive-airway pressure to the nondependent lung. Hemodynamic variables and temperature are shown in Table 2. Small statistically significant changes were observed in mean arterial pressure. Table 3 shows arterial blood gas variables between the 2 groups at the defined measurement points. During OLV, SpO_2 values in both groups were maintained around 95%, resulting in approximately 150 mmHg in PaO_2/F_IO_2. $PaCO_2$ values in both groups were maintained around 40 mmHg. Hypoxemia (SpO_2 <90)[20] during OLV was not observed in either group throughout the study period.

Jugular blood gas data are shown in Table 4. PjO_2 values in

Table 2. Hemodynamic Variables and Temperature

	2-Lung Ventilation	15 min During OLV	30 min During OLV	15 min After 2-Lung Ventilation
BIS value				
Propofol	53 ± 8	51 ± 7	52 ± 6	51 ± 7
Sevoflurane	54 ± 9	51 ± 8	52 ± 9	53 ± 9
Heart rate (beats/min)				
Propofol	72 ± 9	75 ± 11	74 ± 10	74 ± 11
Sevoflurane	71 ± 10	78 ± 11	77 ± 11	77 ± 10
Mean arterial pressure (mmHg)				
Propofol	75 ± 11	80 ± 13	82 ± 15	86 ± 13*
Sevoflurane	75 ± 9	78 ± 12	80 ± 8	75 ± 10
Rectal temperature (°C)				
Propofol	36.4 ± 0.5	36.2 ± 0.5	36.2 ± 0.5	36.6 ± 0.7
Sevoflurane	36.4 ± 0.6	36.3 ± 0.6	36.3 ± 0.6	36.7 ± 0.7

NOTE. Data are expressed as mean ± standard deviation.
*p < 0.05 for the propofol group versus the sevoflurane group.