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Effects of sevoflurane compared with those of isoflurane on arterial oxygenation and hemodynamics during one-lung ventilation

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Abstract

Purpose. This study was designed to compare the effects of sevoflurane and isoflurane on Pao_2 and hemodynamic variables during one-lung ventilation (OLV) in surgical patients.

Methods. Twelve patients undergoing an esophageal procedure with thoracotomy for which a long period of OLV was required were studied using a randomized crossover design. Group 1 received 1.2% isoflurane from the induction of anesthesia until 30 min after starting OLV, and then received 1.7% sevoflurane during the remaining period. In group 2, the order of the anesthetics was reversed. All experimental procedures were performed in the left lateral decubitus position with the chest opened. Arterial and mixed venous blood gases and cardiac outputs were analyzed immediately before OLV, during OLV, and after resumption of two-lung ventilation (TLV).

Results. OLV produced lower Pao_2 and higher venous admixture (Q_s/Q_t) values than TLV. However, there was no significant difference between sevoflurane and isoflurane in Pao_2 or Q_s/Q_t during OLV. Other hemodynamic variables except for $P\bar{v}o_2$ showed no significant differences between the anesthetics.

Conclusion. The effects of sevoflurane on Pao_2 and the hemodynamic variables were similar to those of isoflurane during TLV and OLV in the lateral decubitus position.

Key words: Sevoflurane, Isoflurane, One-lung ventilation

Introduction

One-lung ventilation (OLV) provides a better surgical field for thoracic procedures in the lateral decubitus position. However, clinical studies have reported that unacceptably low levels of arterial oxygenation (Pao_2) occurred in 9%–27% of cases during OLV [1,2]. Thus, maintenance of adequate Pao_2 is still one of the most important factors for successful OLV.

Clinically applicable measures to maintain optimal Pao_2 during OLV are high inspired oxygen concentration, intermittent inflation of the nondependent lung, continuous positive airway pressure to the nondependent lung, and positive end-expiratory pressure to the dependent lung. The choice of anesthetics could also affect Pao_2 during OLV. It was reported that isoflurane provided superior Pao_2 during OLV compared with halothane [3] or enflurane [4]. The present study was carried out to evaluate the effects of sevoflurane on Pao_2 and hemodynamics during OLV compared with those of isoflurane using a randomized crossover design.

Materials and methods

The study was approved by the Ethics Committee for Human Study of Nagasaki University Hospital, and informed consent was obtained from each patient. Twelve patients with ASA physical status 1 or 2 undergoing an esophageal procedure with thoracotomy for which a long period of OLV was required were studied. To avoid the effects of surgical manipulation on the nondependent lung, the subjects did not include patients undergoing pneumonectomy. Patients who had significant respiratory or cardiovascular diseases were excluded.

No preanesthetic medication was administered. On admission to the operating room, peripheral intravenous lines were established. An epidural catheter was inserted at the T7–8 interspace through a Touhy needle via a paramedian approach, but no epidural medication was administered until the end of measurements. The patient was monitored by pulse oximetry, electrocardiogram, rectal thermistor probe, urine output, peak airway pressure, and radial artery catheter for direct

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arterial blood pressure measurement and arterial blood gas sampling. A pulmonary artery catheter was inserted through the right subclavian vein after induction of anesthesia. The transducers attached to these two catheters were zeroed at the vertical level of the left atrium in the lateral decubitus position. End-tidal concentrations of anesthetics and carbon dioxide were measured with a gas analyzer M 1025 B (Hewlett Packard, Palo Alto, CA, USA) that was calibrated before the study. This gas analyzer automatically detected halogenated anesthetics. When two halogenated anesthetics were present in the inspired or expired gas, the anesthetic with the higher concentration was automatically detected.

Anesthesia was induced with thiopental, $3\,mg\cdot kg^{-1}$, and fentanyl, $3\,\mu g\cdot kg^{-1}$, given intravenously. Vecuronium, $0.15\,mg\cdot kg^{-1}$, was used to facilitate tracheal intubation with a Univent tube (Fuji Systems, Tokyo, Japan) by direct laryngoscopy. Patients were mechanically ventilated with ACE-3000a (Acoma Medical Industry, Tokyo, Japan) in a volume-controlled mode in the left lateral decubitus position. Patients were randomly allocated to one of two groups. In group 1 ($n = 6$), the patients received 1.2% (1.0 minimum alveolar concentration [MAC] [5]) isoflurane–100% oxygen from induction until 30 min after starting OLV, and then received 1.7% (1.0 MAC [6]) sevoflurane–100% oxygen during the remaining period. In group 2 ($n = 6$), the order of the anesthetics was reversed (Fig. 1). Isoflurane and sevoflurane were delivered using I and S type MK III vaporizers (Acoma Medical Industry). The fresh gas flow rate was set at $6\,l\cdot min^{-1}$ in both groups after tracheal intubation until the end of the measurements. The tidal volume and I:E ratio were set at $10\,ml\cdot kg^{-1}$ and 1:2 during both OLV and two-lung ventilation (TLV) at a rate adjusted to maintain the arterial carbon dioxide ($Paco_2$) between 35 and 40 mmHg.

The endobronchial blocker was advanced through its anterior channel and directed into the right main-stem bronchus under direct vision with a fiberoptic bronchoscope. The patient was then turned to the lateral decubitus position. The position of the bronchial blocker cuff was checked just before starting OLV, and the effectiveness of lung collapse was monitored during OLV by direct observation of the collapsed nondependent lung in the operative hemithorax. Intravenous fluids and fentanyl were administered so that the mean arterial pressure (MAP) varied by less than 15% from preinduction values. Additional doses of vecuronium were administered to achieve an approximately 90%–95% motor blockade, as indicated by a blockade monitor.

The experimental protocol is shown in Fig. 1. All experimental procedures were performed with the patient in the left lateral decubitus position with the chest opened during surgical manipulation. Arterial blood samples were obtained during TLV just before the initiation of OLV, every 10 min during OLV for 60 min, and after the resumption of TLV. The blood samples were analyzed with an ABL 250 blood gas analyzer (Radiometer, Copenhagen, Denmark). Cardiac output (CO) and mixed venous oxygen partial pressure ($P\bar{v}o_2$) were measured during TLV just before the initiation of OLV, after 30 and 60 min of OLV, and after resumption of TLV. Oxygen consumption ($\dot{V}o_2$) was calculated from the Fick equation and venous admixture (Q_s/Q_t) from standard formulas.

The data are expressed as means ± SEM. All variables of patients in group 1 and 2 were compared by Student's t-test. The effects of anesthetics on arterial blood gases and hemodynamic variables were compared by analysis of variance with Fisher's least significant difference test for multiple comparisons. When significant differences were found, Tukey's test was used for post-hoc testing, and paired and unpaired t-tests were used as appropriate. A probability value of less than 0.05 was regarded as significant.

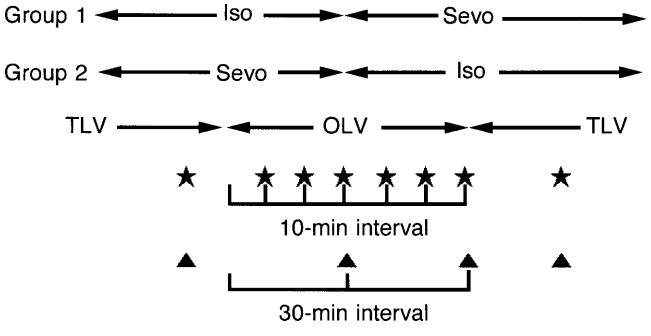

Fig. 1. Experimental protocol. All experimental procedures were performed with the patient in the left lateral decubitus position with chest opened during surgical manipulation. *Stars*, arterial blood gas sampling; *triangles*, cardiac output measurement and mixed venous blood gas sampling; *ISO*, isoflurane; *SEVO*, sevoflurane; *TLV*, two-lung ventilation; *OLV*, one-lung ventilation

Results

There was no patient whose Spo_2 decreased to below 90%, or whose nondependent lung was reinflated before completion of the study protocol. There were no significant differences in the measured variables attributable to the order of administration of anesthetics, i.e., group 1 *vs* group 2. Therefore, the mean ± SEM values represent the pooled data from both groups. The preoperative data for patients are shown in Table 1.

Table 1. Preoperative data for all patients ($n = 12$)

Age (yr)	47 ± 8
Sex (M/F)	9/3
Weight (kg)	55 ± 3
Height (cm)	160 ± 2
$FEV_{1.0}$ (%)	81 ± 2
FVC (%)	110 ± 5
Pa_{O_2} (mmHg)	91 ± 6
Pa_{CO_2} (mmHg)	40 ± 1

Values are expressed as means ± SEM or number of patients

Table 2. Arterial blood gases during TLV and after 30-min OLV

	TLV		After 30-min OLV	
Value	SEVO	ISO	SEVO	ISO
pH	7.43 ± 0.01	7.42 ± 0.01	7.41 ± 0.01	7.45 ± 0.01
Pa_{O_2} (mmHg)	390 ± 28	434 ± 18	247 ± 35*	221 ± 35*
Pa_{CO_2} (mmHg)	36 ± 1	35 ± 1	39 ± 1	38 ± 1
Hco_3^- ($mEq \cdot l^{-1}$)	23.7 ± 0.5	24.0 ± 0.6	23.9 ± 0.5	24.1 ± 0.6
Base excess ($mEq \cdot l^{-1}$)	0.34 ± 0.5	0.02 ± 0.9	−0.10 ± 0.6	0.26 ± 0.6

Values are expressed as means ± SEM ($n = 12$)
TLV, two-lung ventilation; OLV, one-lung ventilation; SEVO, sevoflurane; ISO, isoflurane
*Significantly different from TLV values ($P < 0.05$)

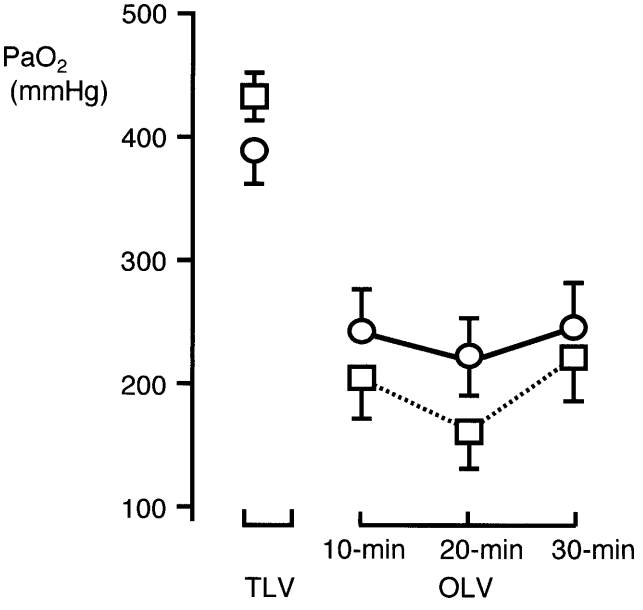

Fig. 2. Pa_{O_2} during TLV and OLV. Values are expressed as means ± SEM ($n = 12$). *TLV*, two-lung ventilation; *OLV*, one-lung ventilation; *circles*, sevoflurane; *squares*, isoflurane

Arterial blood gas data during TLV and OLV with 1 MAC sevoflurane or isoflurane are shown in Table 2 and Fig. 2. The values of pH, Pa_{CO_2}, Hco_3^-, and base excess did not significantly differ according to experimental conditions. The Pa_{O_2} values after 10, 20, and 30 min of OLV were significantly lower than those during TLV in both sevoflurane and isoflurane administration. The Pa_{O_2} values after 10, 20, and 30 min of OLV did not significantly differ during sevoflurane and isoflurane administration.

Table 3 shows the hemodynamic variables during TLV and OLV. Q_s/Q_t values were significantly higher during OLV than during TLV with both anesthetics. However, there were no significant differences between sevoflurane and isoflurane administration. No other hemodynamic variables, i.e., heart rate, MAP, pulmonary artery occlusion pressure, CO, pulmonary vascular resistance, or $\dot{V}o_2$, differed significantly between the two anesthetics. $P\bar{v}o_2$ during OLV was significantly higher with sevoflurane than with isoflurane.

Discussion

The present study shows that the effects of sevoflurane on Pa_{O_2} and the hemodynamic variables that might influence Pa_{O_2} during TLV and OLV are similar to those of isoflurane. Abe et al. [7] studied the effects of sevoflurane and isoflurane on Pa_{O_2}, hemodynamics, and shunt fraction during OLV in patients undergoing lobectomy for lung cancer. Our results were similar to theirs. Otherwise, Pa_{O_2} values were higher and Q_s/Q_t values were lower than theirs during OLV. The different results for Pa_{O_2} and Q_s/Q_t values may be due to the

Table 3. Hemodynamic variables during TLV and after 30-min OLV

	TLV		After 30-min OLV	
Value	SEVO	ISO	SEVO	ISO
HR (beats·min^{-1})	60 ± 9	75 ± 5	75 ± 3	77 ± 4
MAP (mmHg)	84 ± 4	92 ± 6	87 ± 3	87 ± 3
PCWP (mmHg)	8.8 ± 0.5	9.2 ± 1.0	10.0 ± 0.9	10.0 ± 0.9
CO (l·min^{-1})	4.5 ± 0.3	4.8 ± 0.4	4.6 ± 0.1	4.8 ± 0.2
PVR (dyne·s/cm^5)	97 ± 11	115 ± 14	117 ± 12	116 ± 17
$P\bar{v}o_2$ (mmHg)	50.3 ± 1.8	46.5 ± 1.5	53.8 ± 1.4	46.3 ± 0.9**
$\dot{Q}_s/\dot{Q}_t$ (%)	21.4 ± 2.0	19.6 ± 1.4	30.2 ± 2.6*	30.1 ± 2.2*
$\dot{V}o_2$ (ml·min^{-1})	139 ± 13	141 ± 6	132 ± 10	132 ± 8

Values are expressed as means ± SEM ($n = 12$)
TLV, two-lung ventilation; OLV, one-lung ventilation; SEVO, sevoflurane; ISO, isoflurane; HR, heart rate; MAP, mean arterial pressure; PCWP, pulmonary capillary wedge pressure; CO, cardiac output; PVR, pulmonary vascular resistance; $P\bar{v}o_2$, mixed venous oxygen partial pressure; $\dot{Q}_s/\dot{Q}_t$, venous admixture; $\dot{V}o_2$ = oxygen consumption
* Significantly different from TLV values ($P < 0.05$)
** Significantly different between SEVO and ISO ($P < 0.05$)

following. First, there was the possibility that the auto-positive end-expiratory pressure (auto-PEEP) would decrease $\dot{Q}_s/\dot{Q}_t$ and increase Pao_2 during OLV in our study. Auto-PEEP could be demonstrated during anesthesia for thoracic surgery in a large proportion of patients and had been implicated in the improvement of the ventilation-perfusion relationship during OLV by increasing functional residual capacity [8,9]. The patients' respiratory mechanics (respiratory system resistance and compliance), added resistance (endotracheal tube, ventilator tubing, and devices), and ventilator setting would be synergistic in producing auto-PEEP in our patients, but not in Abe's patients. Second, the experimental methods might influence the result. We used a crossover design. Third, to avoid the effects of surgical manipulation on the nondependent lung, our subjects did not include patients undergoing pneumonectomy. These factors would influence the differences in Pao_2 and $\dot{Q}_s/\dot{Q}_t$ values during OLV.

Volatile halogenated anesthetics are popular maintenance anesthetics during thoracic surgery, for several reasons. First, the halogenated drugs have a salutary effect on airway irritability. Second, since the volatile halogenated anesthetics can be rapidly titrated and eliminated, the risk of postoperative hypoventilation may be diminished. Third, although the halogenated anesthetics decrease hypoxic pulmonary vasoconstriction (HPV), they do not appear to decrease Pao_2 more than intravenous anesthetics [3,10]. Halothane in humans [3] and isoflurane in dogs [11] have been demonstrated to cause inhibition of HPV. Ishibe et al. [12] reported that sevoflurane also inhibited HPV in a dose-related manner, and its potency was similar to that of isoflurane in the perfused rabbit lung. However, some studies showed that isoflurane had only a small inhibitary effect on HPV [3] and that the effect of 1%–1.5% isoflurane on HPV was almost unmeasurable in humans [13]. Reid et al. [14] reported that Pao_2 during OLV with 1 MAC isoflurane was not significantly different from that with propofol-alfentanyl anesthesia. These results suggest that all volatile halogenated anesthetics inhibit HPV in vitro but that the inhibition is attenuated in vivo. Circulatory depression, sympathetic inactivation, and hormonal alteration would modulate the HPV response in vivo.

There are several factors that influence Pao_2 during OLV. CO is also known to be one of the important factors that influence Pao_2. Slinger et al. [4] showed that Pao_2 had a positive correlation with CO during OLV with 1 MAC enflurane and isoflurane. Nomoto et al. [15] showed that increases in CO using inotropic agents led to an increase in Pao_2 during OLV. The most likely mechanism was an increased $P\bar{v}o_2$ secondary to an increase in CO. On the other hand, it was reported that a greater CO during OLV caused dilation of the pulmonary vasculature and inhibited HPV [10].

In our study, there were no differences in hemodynamic variables, except for Pvo_2, between sevoflurane and isoflurane during TLV or during OLV in the lateral decubitus position. This result would coincide with previous reports that the cardiovascular effects of sevoflurane are similar to those of isoflurane [16,17]. The significant difference between two anesthetics in $P\bar{v}o_2$ values during OLV might reflect the slightly higher Pao_2 value with sevoflurane compared with isofluranre.

In summary, the effects of sevoflurane on Pao_2 and the hemodynamic variables are similar to those of isoflurane during TLV and OLV in the lateral decubitus position.

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