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Hemodynamic and bispectral index responses to tracheal intubation during isoflurane or sevoflurane anesthesia

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Abstract
Purpose. The effects of volatile anesthetics on change in the bispectral index (BIS) due to tracheal intubation are unclear. We investigated hemodynamic and BIS responses to intubation during isoflurane or sevoflurane anesthesia.
Methods. After obtaining Institutional Review Board approval and informed consent, we randomly allocated 40 patients of American Society of Anesthesiologists (ASA) physical status I to receive either isoflurane (ISO group; n = 20) or sevoflurane (SEV group; n = 20). The patients were anesthetized with thiamylal and were ventilated with 100% oxygen, using a mask. The inspired concentrations of isoflurane and sevoflurane were gradually increased and maintained at end-tidal anesthetic concentrations of 2 minimum alveolar concentration (MAC) during the study period. Tracheal intubation was performed 15 min after the end-tidal anesthetic concentrations had reached 2 MAC. Mean arterial pressure (MAP), heart rate (HR), and BIS were recorded before induction, at the loss of consciousness, before laryngoscopy, and at 1, 3, and 5 min after intubation.
Results. Anesthesia with 2 MAC volatile anesthetics increased HR in the ISO group, and decreased MAP in the SEV group. The BIS value decreased from 95 ± 3 and 96 ± 2 before thiamylal to 39 ± 9 and 38 ± 10 before intubation in the ISO and SEV groups, respectively. MAP and HR were significantly increased in both groups 1 and 3 min after intubation, but BIS remained unchanged.
Conclusion. Anesthesia with 2 MAC of isoflurane and sevoflurane was effective to suppress the change in BIS due to intubation but was not sufficient to prevent changes in hemodynamic responses.

Key words Bispectral index · Tracheal intubation · Isoflurane · Sevoflurane

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Introduction

The bispectral index (BIS), obtained by bispectral analysis of an electroencephalogram (EEG), has been shown to be related to the hypnotic component of anesthesia [1,2]. Several studies have demonstrated an increase in BIS associated with tracheal intubation in patients anesthetized with intravenous anesthetics such as propofol, fentanyl, and remifentanil [3–5]. However, to our knowledge, there have been no reports on the effects of volatile anesthetics on changes in BIS due to intubation. Because volatile anesthetics have both hypnotic and antinociceptive properties, they are likely to attenuate BIS responses to intubation more effectively than intravenous anesthetics. The objective of the present study was to investigate the changes in hemodynamic and BIS responses to laryngoscopy and tracheal intubation during isoflurane or sevoflurane anesthesia.

Subjects and methods

After obtaining approval from the Institutional Ethics Committee and informed consent from each patient, we randomly allocated 40 patients of American Society of Anesthesiologists (ASA) physical status I, aged 25–65 years, scheduled for elective surgery, into two groups, to receive either isoflurane (ISO group; n = 20) or sevoflurane (SEV group; n = 20). None of the patients had cardiopulmonary or neurological disorders.

No sedative premedication was given before surgery. Electrocardiograms (ECGs) and hemoglobin oxygen saturation ($S_{P_{O_2}}$) were monitored continuously. Mean arterial pressure (MAP) and heart rate (HR) were measured by an automatic oscillometric method (M1008B; Agilent Technologies, Boeblingen, Germany). BIS (version 3.4) was measured continuously on an EEG monitor (Model A1050; Aspect Medical Systems, Natick, MA, USA) using BisSensor strips (Aspect

Medical Systems). The strips consisted of three pregelled electrodes, two active and one ground. The impedance of each electrode was maintained at less than 2 K ohms. A soft catheter was inserted about 2 cm into the nostril to monitor end-tidal carbon dioxide and end-tidal concentrations of isoflurane and sevoflurane (Anesthetic Gas Module M1026A; Agilent Technologies). We assumed minimum alveolar concentration (MAC) values for isoflurane and sevoflurane of 1.15% [6] and 1.71% [7], respectively.

After administering oxygen by face mask, anesthesia was induced with intravenous thiamylal 2 mg·kg^{-1}. After the patient showed loss of consciousness, vecuronium 0.1 mg·kg^{-1} was given intravenously, and the patient's lungs were ventilated by mask inhalation of isoflurane or sevoflurane at 0.5 MAC in 100% oxygen (6 l·min^{-1}) via a semiclosed circle system. End-tidal carbon dioxide tension was maintained at 40 ± 5 mmHg. The end-tidal concentration of isoflurane or sevoflurane was gradually increased to 2 MAC by adjusting the patient's inspired concentration, and was held there for 15 min. Then, the trachea was intubated by one of the authors (M.N.), and the lungs were ventilated with the same end-tidal anesthetic concentration (2 MAC) for 5 min. No additional drugs were given during the study period.

MAP, HR, and BIS were recorded before the induction of anesthesia (baseline); at the loss of consciousness; immediately before laryngoscopy; and at 1, 3, and 5 min after intubation. Surgery was begun after all measurements had been completed.

We considered a 10% difference in percentage changes in BIS relative to baseline level between the groups to be important. Therefore, 20 patients in each group would be necessary to detect such a difference if $\alpha = 0.05$ and $\beta = 0.1$. All data values were expressed as means ± SD. Statistical analysis was performed using one-way analysis of variance (between groups) and a repeated-measures analysis of variance (within groups). Post-hoc analyses were performed with Fisher's protected least significant difference test. The χ^2 test was used to compare differences in sex ratios between the two groups. *P* values of less than 0.05 were considered statistically significant.

Results

The two groups were comparable with regard to sex ratio, age, height, and weight (Table 1). Baseline MAP, HR, and BIS values were not significantly different between the two groups (Table 2). The end-tidal anesthetic concentrations reached 2 MAC at 7 ± 1 min and 5 ± 1 min after induction in the ISO and SEV groups, respectively. The duration of laryngoscopy and tracheal intubation did not exceed 1 min in any of the patients. None of the patients had an abnormal ECG, hypotension needing a vasoconstrictor, or an S_{pO_2} value of less than 98%.

Anesthetic induction with thiamylal did not change MAP and HR, but significantly decreased BIS in both groups. After the inhalation of anesthetics, MAP decreased significantly in the SEV group, and HR increased significantly in the ISO group. Consequently, MAP and HR before laryngoscopy showed significantly higher values in the ISO group than in the SEV group. Inhalation of the two anesthetics decreased BIS values to 39 ± 9 and 38 ± 10 before intubation in the ISO and SEV groups, respectively. In both groups, laryngoscopy and intubation caused significant increases in MAP and HR, but no change in BIS. These changes were comparable in the two groups.

Table 1. Demographic data

	Isoflurane	Sevoflurane
Sex (female/male) (*n*)	12/8	10/10
Age (years)	46 ± 8	44 ± 10
Weight (kg)	68 ± 12	71 ± 10
Height (cm)	166 ± 10	165 ± 8

Values are means ± SD

Table 2. Mean arterial pressure (MAP), heart rate (HR), and bispectral index (BIS)

	MAP (mmHg)		HR (bpm)		BIS	
	Isoflurane	Sevoflurane	Isoflurane	Sevoflurane	Isoflurane	Sevoflurane
Baseline	92 ± 8	94 ± 10	75 ± 9	69 ± 12	95 ± 3	96 ± 2
Loss of consciousness	90 ± 7	92 ± 8	68 ± 5	64 ± 7	74 ± 11*	76 ± 10*
Before laryngoscopy	86 ± 13	62 ± 10*,**	87 ± 10*	62 ± 9**	39 ± 9*	38 ± 10*
1 min after intubation	114 ± 17*	109 ± 21*	105 ± 13*	106 ± 15*	39 ± 10*	41 ± 11*
3 min after intubation	107 ± 20*	102 ± 22*	80 ± 15*	88 ± 16*	42 ± 9*	44 ± 10*
5 min after intubation	88 ± 11	83 ± 17	69 ± 13	65 ± 9	40 ± 11*	43 ± 12*

* $P < 0.05$ compared with baseline; ** $P < 0.05$ compared with the isoflurane group
Values are means ± SD

Discussion

This study demonstrated that 2 MAC of isoflurane and sevoflurane induced different circulatory changes, although the decreases in BIS values during anesthesia with isoflurane and with sevoflurane were similar. Moreover, these anesthetics attenuated the increase in BIS associated with tracheal intubation, but did not prevent changes in hemodynamic responses.

Inhalational anesthetics are known to produce dose-dependent effects on BIS [8–11]. Glass et al. [8] reported that BIS and the sedation score concomitantly decreased as the end-tidal isoflurane concentration increased from 0.25% to 1.0%. Katoh et al. [9] reported inverse relationships of BIS to sevoflurane concentrations ranging from 0.2% to 1.4% in adult patients. These reductions in BIS are reported to reach a plateau at values of about 40 with increases in isoflurane and sevoflurane concentrations beyond 1 MAC. In the current study, BIS remained stable in both groups when tracheal intubation was performed after the end-tidal concentrations of anesthetics reached 2 MAC.

Both MAP and HR before intubation were greater in the ISO group than in the SEV group. The pungency of volatile anesthetics stimulates the airway receptors, which induces reflex sympathetic activation [12–14]. Isoflurane evoked greater airway irritation than did sevoflurane [15]. Thus, differing airway irritating effects between isoflurane and sevoflurane might be one of the reasons for their different effects on hemodynamic variables.

It has been suggested that a reflex response to a noxious stimulus due to intubation is mediated at the subcortical level [3], and thus may be unrelated to the BIS value [8]. However, peripheral noxious stimuli reach the brain through the ascending reticular activating systems of the brain stem [16]. Mi et al. [3] reported that BIS was significantly increased by laryngoscopy and intubation during the infusion of propofol with or without fentanyl pretreatment. Guignard et al. [4] demonstrated that laryngoscopy and intubation were associated with an increase in BIS during target-controlled infusion of propofol, and they showed that the administration of remifentanil attenuated these BIS changes. In contrast to these reports, there were no increases in BIS after laryngoscopy and intubation in the present study, suggesting that 2 MAC of isoflurane and sevoflurane was sufficient to prevent the arousal response to tracheal intubation.

MAP and HR increased significantly in both groups after intubation despite the fact that there were no changes in BIS. This may be related to the predominant hypnotic effects of inhaled anesthetics with a weak subcortical antinociceptive action. The similar changes in hemodynamics and BIS in response to intubation indicated that there was no difference in antinociceptive and hypnotic effects between isoflurane and sevoflurane.

Our use of thiamylal for induction of anesthesia may have influenced the circulatory and BIS changes induced by intubation. We previously found that $3\,mg \cdot kg^{-1}$ of thiamylal for induction of anesthesia influenced the hemodynamics in the first 5 min [13]. Moreover, Flaishon et al. [17] reported that recovery of consciousness was achieved about 5 min after the administration $4\,mg \cdot kg^{-1}$ of thiopental. As we performed intubation at least 20 min after induction, we believe that thiamylal had only a minimal effect on the results of the current study.

In conclusion, during the inhalation of isoflurane and sevoflurane at end-tidal concentrations of 2 MAC, tracheal intubation increased HR and MAP without affecting BIS. These results indicate that these concentrations of isoflurane and sevoflurane are effective in blunting the intubation-induced arousal response, but are not sufficient to prevent changes in hemodynamic responses.

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