J Anesth (1994) 8:178–181

Journal of
Anesthesia

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Single-breath induction of anesthesia: comparison of enflurane and sevoflurane

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Abstract: In this study induction of anesthesia using the single-breath technique with either enflurane or sevoflurane in oxygen was compared. Each group consisted of 16 unpremedicated volunteers who breathed approximately 1.7 minimum alveolar concentration (MAC) equivalents of either vapor. There were no significant differences in the cardiovascular and respiratory variables monitored. The induction of anesthesia with enflurane (141 ± 41 s) required significantly more time than with sevoflurane (118 ± 25 s). The enflurane group was associated with significantly more problems during induction, and showed moderate or sometimes severe excitatory movements of the extremities and/or coughing. Subjects in the enflurane group described the induction of anesthesia as less pleasant than in the sevoflurane group. We concluded that enflurane was less suitable for single-breath induction of anesthesia compared with sevoflurane.

Key words: Enflurane, Sevoflurane, Single-breath induction

Introduction

The most widely used inhalational anesthetic in the United States and Canada is isoflurane [1]. In Japan, however, newly developed sevoflurane has recentry surpassed isoflurane. Halothane and enflurane are falling in popularity but are still used. We had already studied the characteristics of inhalational induction of anesthesia using single-breath techniques with isoflurane and halothane compared to sevoflurane [2,3]. The current report focused on single-breath techniques using the remaining anesthetic, enflurane, and compared it to sevoflurane.

Address correspondence to: M. Yurino
Received for publication on July 8, 1993; accepted on November 16, 1993

Patients and methods

After obtaining approval from our Hospital Human Research Committee and obtaining informed consent from the patients, we studied 32 healthy adult volunteers randomly assigned to receive either 2.95% enflurane in oxygen or 3.0% sevoflurane in oxygen. These concentrations represented approximately 1.7 minimum alveolar concentration (MAC) equivalents of each agent [4,5]. Sixteen subjects were assigned to the enflurane group and 16 subjects to the sevoflurane group. None were premedicated.

A fresh gas flow of 8 $l \cdot min^{-1}$ was delivered from an Ohmeda anesthetic machine (Model Excel, Ohmeda, Madison, U.S.A.) fitted with Ohmeda calibrated vaporizers. In each experiment, the circle system was primed with each vapor at the desired concentration. The anesthetic bag was filled and the excess gas was vented through the popoff valve.

The volunteers were breathing room air before induction of anesthesia. They were instructed to breathe out to residual volume and then the anesthetic system and mask were applied gently to their faces. They were told to take a vital capacity breath and to hold their breath for as long as was comfortable. Following the vital capacity breath, the volunteers, through spontaneous respiration, were given the same anesthetic mixture for up to 5 min from the end of their vital capacity breath. After that, the subjects continued to breathe oxygen until they regained consciousness.

Monitoring included an automatic noninvasive blood pressure recorder with an ECG oscilloscope and pulse oximetry (Nihon Colin, Nagoya, Japan) and multigas monitor (Datex, Helsinki, Finland). Respiratory gases were sampled from the elbow connector with mask at a rate of 150 $ml \cdot min^{-1}$ into a multigas monitor to continuously monitor end-tidal and inspired concentrations of anesthetic gases. From these data, sevoflurane and enflurane concentrations were recorded.

Loss of consciousness was defined as the failure to respond to verbal commands. Verbal commands were repeated at 10-s intervals until the subjects failed to respond. Induction time and the presence of excitatory phenomena were recorded by an independent observer. Induction time was defined as the time between the end of the vital capacity inspiration and the loss of consciousness.

We assessed an anesthetic induction as complicated if one or more problems occurred. We grouped complications into the five categories established by Lamberty and Wilson [6]. A single cough, laryngospasm, breath holding, movement of a limb, or excessive salivation (defined as enough secretions to wet our hands) were recorded.

The observer, who did not know which anesthetic agent was used, asked the subjects to characterize the smell of the anesthetic agents, and whether they had any objection to undergoing similar induction technique again, immediately after emergence from anesthesia.

All results are expressed as means ± SD. Statistical analyses were carried out using analysis of variance (ANOVA), chi-square testing, and Student's *t*-test, as appropriate. P values less than 0.05 were considered to be statistically significant.

Results

The groups were demographically similar with no significant differences in terms of age, sex, weight, or height (Table 1). Anesthesia was successfully induced in 16 subjects in the sevoflurane group and in 15 subjects in the enflurane group. One induction in the enflurane group had to be abandoned because the subject experienced severe excitatory movements and coughing.

The mean value of induction time was shorter with enflurane than with sevoflurane (141 ± 41 s and 118 ± 25 s, respectively; $P < 0.05$). The end-tidal enflurane concentrations increased more slowly than those of sevoflurane. Figure 1 shows the end-tidal concentrations of each anesthetic.

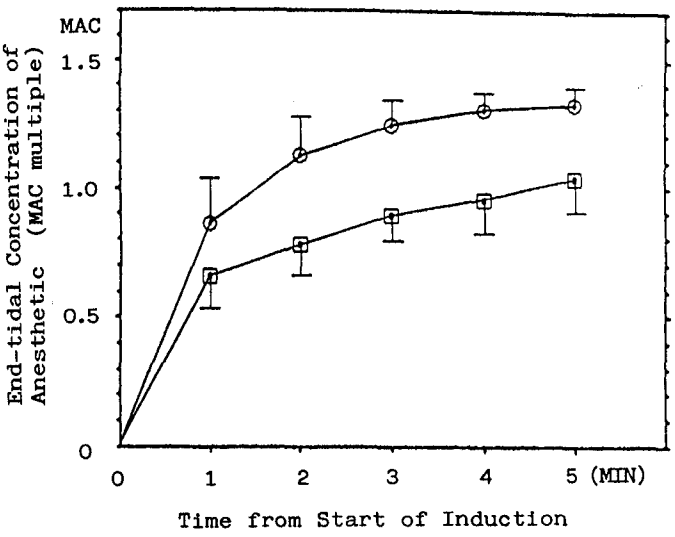

Fig. 1. End-tidal concentration (ex/rend as MAC multiple) of sevoflurane (*circles*) increased more rapidly with single breath induction technique than enflurane (*squares*). Data are means ± SD

Cardiovascular stability was similar in both groups. Systolic and diastolic blood pressures gradually decreased significantly but stayed within safe levels. Heart rate was stable in both groups (Table 2). There were no significant differences between enflurane and sevoflurane with respect to arterial oxygen saturation (Sao_2). Sao_2 increased 98% or more following application of the anesthetic mask.

The five most common problems of inhalation anesthetic induction are presented (Table 3). Overall, the enflurane group had more problems than did the sevoflurane group. Excitatory movements were of mild intensity in the sevoflurane group but coughing and movements were moderate or sometimes severe in the enflurane group. Serious problems such as severe movements, coughing, laryngospasm, breath holding, and excessive salivation did not occur in the sevoflurane group.

A survey of subjects after emergence from anesthesia revealed that the experience was viewed mostly positively; 88% would have accepted the technique again in the sevoflurane group and 80% in the enflurane group.

Table 1. Demographic data of subjects

			Age (years)	Weight (kg)	Height (cm)
	Males	Females	Mean ± SD (range)	Mean ± SD (range)	Mean ± SD (range)
Sevoflurane (n = 16)	11	5	25.8 ± 3.9 (23–36)	59.9 ± 9.1 (48–74)	168.2 ± 7.8 (158–182)
Enflurane (n = 16)	13	3	25.0 ± 2.2 (23–32)	62.8 ± 7.3 (48–74)	169.7 ± 6.3 (155–177)

Table 2. Comparison of cardiovascular stability between anesthetics

	Before induction	After induction, Time (min)				
	Control	1	2	3	4	5
Sevoflurane (n = 16)						
Systolic BP (mmHg)	124	120	117*	112*	108*	105*
	(20)	(15)	(13)	(16)	(14)	(13)
Diastolic BP (mmHg)	69	67	65*	59*	57*	55*
	(11)	(13)	(15)	(15)	(14)	(14)
Heart rate (beats/min)	79	78	77	77	76	74
	(14)	(18)	(12)	(12)	(13)	(13)
Enflurane (n = 15)						
Systolic BP (mmHg)	128	126	120	115*	110*	107*
	(10)	(16)	(18)	(11)	(13)	(12)
Diastolic BP (mmHg)	73	69	66	62*	58*	55*
	(8)	(9)	(10)	(9)	(9)	(8)
Heart rate (beats/min)	74	70	73	72	68	69
	(13)	(14)	(12)	(13)	(12)	(11)

BP, blood pressure.
Values represent mean (SD).
* $P < 0.05$ control *vs* each value.

Table 3. Incidence of complications during induction of anesthesia

	Sevoflurane (n = 16)	Enflurane (n = 16)
Induction		
Complicated*	2/16 (12.5%)	9/16 (56.25%)
Uncomplicated	14/16 (87.5%)	7/16 (43.75%)
Coughing	–	4/16 (25.0%)
Larygospasm	–	–
Breath holding	–	–
Movements	2/16 (12.5%)	6/16 (37.5%)
Secretions	–	–
Aborted	–	1/16 (6.25%)

* $P < 0.05$ between groups.

Table 4. Acceptability and smell

	Sevoflurane	Enflurane
Same induction again?		
Yes	14/16 (87.5%)	12/15 (80.0%)
No comment	–	–
No	2/16 (12.5%)	3/15 (20.0%)
Smell		
Pleasant	19/16 (56.25%)*	3/15 (20.0%)
No comment	2/16 (12.5%)	5/15 (33.3%)
Unpleasant	5/16 (31.25%)	7/15 (46.7%)

* $P < 0.05$.

Nonetheless, the number of patients in the sevoflurane group who described the anesthetic as having a pleasant smell was significantly higher than in the enflurane group (Table 4).

Discussion

We have previously demonstrated the safety and acceptability of the single-breath induction technique using sevoflurane in oxygen and compared it to the MAC equivalents of isoflurane or halothane [2,3]. One study [2] showed that 2% isoflurane has a similar or slightly slower induction than 3% sevoflurane, and that it has severe problems leading to complications during induction. In the sevoflurane group, neither coughing nor breath holding occurred but slight finger movements were observed in 12% of the subjects. However, subjects with isoflurane were significantly more prone to coughing and excitatory movements; small and sometimes excessive movements of the extremities were observed in 43% of the subjects beginning with coughing due to its pungency. Isoflurane was inferior to sevoflurane as an anesthetic agent using single-breath induction.

Another study [3] showed that both 2% halothane and 4.5% sevoflurane are effective in single-breath induction of anesthesia. Sevoflurane had fewer problems during induction than did halothane (17.6% *vs* 33.3%, respectively). However, no serious problems such as severe coughing, excitatory movements, laryngospasm, breath holding, or excessive salivation occurred in either group. Subjects in both groups found the induction of anesthesia pleasant and had no objection to undergoing the procedure again. Nevertheless, the slow speed of induction with halothane frustrated the anesthetist because the longer induction time may increase the occurrence of pronounced excitatory phenomena.

The induction time required with halothane was twice as long as sevoflurane.

In this study, we estimated the characteristics of single-breath induction with enflurane to be similar to those with isoflurane. Enflurane required a somewhat longer induction time than sevoflurane. We also found that the end-tidal concentration of enflurane increased more slowly than that of sevoflurane. The findings presented are due to the different solubility coefficients of enflurane and sevoflurane [7]. In clinical practice, however, there is no noticeable difference in induction time between enflurane and sevoflurane; however, the enflurane group had a number of problems leading to complications and one induction had to be aborted because of severe excitatory movements.

Lamberty and Wilson [6] stated that isoflurane with the single-breath induction technique was more acceptable to patients in their pilot study than enflurane, and they chose isoflurane as an alternative to halothane. However, this finding is controversial. On the basis of our experience, induction with isoflurane using the single-breath technique was less acceptable than enflurane. In hind sight, we may have missed an opportunity to undertake a randomized trial of all four anesthetics: enflurane, isoflurane, halothane, and sevoflurane. However, it is noteworthy that the four anesthetic agents were tested by similar methodology and by the same observers, although not at the same time. Doi and Ikeda [8] reported airway irritation produced by halothane, enflurane, isoflurane, and sevoflurane during brief inhalation. They concluded that the severity of subjective airway irritation was least for sevoflurane, followed by halothane and enflurane, and was greatest for isoflurane. Acceptability is not defined solely by airway irritation, but it is an important factor. The acceptability reported by the subjects for sevoflurane and halothane was best, followed by enflurane, and least for isoflurane.

Gaseous induction of anesthesia in adult patients is seldom used in routine practice, and the single-breath induction technique is rare. While intravenous induction is used frequently because patients may progress through the stages of light anesthesia rapidly, resulting in smooth induction. In the present study, we tested sevoflurane with the single-breath induction technique. Sevoflurane provided fast onset of anesthesia and the patients passed through the stages of light anesthesia in much the same way as with intravenous induction agents.

In conclusion, we have shown that enflurane is less suitable for single-breath induction of anesthesia than sevoflurane. Most of the subjects in both groups had no objection to undergoing the procedure again. However, enflurane had some serious problems of induction because of its irritation of the upper airways. In contrast to enflurane, sevoflurane showed good characteristics of anesthetic induction, such as the smooth and rapid induction without severe problems even in cases where premedication was not used.

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