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## End-tidal Sevoflurane Concentration for Tracheal Intubation and Minimum Alveolar Concentration in Pediatric Patients

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**Background:** Sevoflurane is a new inhalational anesthetic agent having low solubility in blood and a relatively nonpungent odor. As such it should be useful as an inhalation induction in pediatric patients. The objectives of the study were to determine both the minimum alveolar concentration (MAC) and the concentration required for tracheal intubation (MAC<sub>ET</sub>) of sevoflurane in pediatric patients.

**Methods:** The study group consisted of 36 ASA physical status 1 elective surgical patients, aged 1–9 yr. MAC<sub>ET</sub> determination: After establishing and maintaining the end-tidal concentration for 15 min, tracheal intubation was attempted with an uncuffed tracheal tube without neuromuscular relaxants or other adjuvants. Each concentration at which tracheal intubation was attempted was predetermined according to the up-and-down method (with 0.5% as a step size). MAC determination: The patients examined were the same as those for MAC<sub>ET</sub> determination except that for the exclusion of those to whom neuromuscular relaxants or other adjuvants drugs were administered. End-tidal sevoflurane concentration was determined according to the up-and-down method (with 0.5% as a step size) and held constant for at least 15 min before a skin incision.

**Result:** MAC<sub>ET</sub> of sevoflurane was 2.69% (95% fiducial limits: 2.23% and 3.37%); MAC of sevoflurane was 2.03% (95% fiducial limits: 1.51% and 2.53%); and the MAC<sub>ET</sub>/MAC ratio was 1.33.

**Conclusion:** Sevoflurane appears to be suitable for use in pediatric patients as an induction agent, permitting tracheal intubation without neuromuscular relaxants. (Key words: Anesthesia; pediatric. Anesthetic techniques: tracheal intubation. Anesthetics, volatile: sevoflurane. Potency, anesthetic: minimum alveolar concentration.)

FREQUENTLY in pediatric patients, anesthesia is induced and the trachea intubated solely with an inhalational agent, such as halothane or enflurane. Sevoflurane is a new polyfluorinated methyl ethyl ether with physical properties that differ from those of halothane or enflurane, including a lower blood-gas partition coefficient.<sup>1-3</sup> The low partition coefficient should facilitate a rapid increase in alveolar and tissue anesthetic partial pressures during induction of anesthesia. With sufficient anesthetic depth, tracheal intubation also may be accomplished. Yakaitis *et al.* have designated MAC<sub>ET</sub> as the end-tidal concentration of inhalational agent at which a smooth tracheal intubation is possible in 50% of patients.<sup>4,5</sup> The objectives of the present study were to determine the minimum alveolar concentration (MAC) of sevoflurane for tracheal intubation (effective concentration in 50% of patients) (MAC<sub>ET</sub>) and skin incision in pediatric patients.

**Materials and Methods**

Informed consent regarding the nature and risks of the study was obtained from the parent or guardian of each participant. The study group consisted of 36 ASA physical status 1 elective surgical pediatric patients, aged 1–9 yr, in whom the proposed surgical procedure included a body surface incision.

A precordial stethoscope was used to monitor heart and breath sounds. Blood pressure was measured indirectly, and lead II of the electrocardiogram (heart rate) was continuously displayed (BP-308ET, Nippon Colin, Aichi, Japan). Breath-by-breath measurements of anesthetic concentration and end-tidal carbon dioxide were facilitated using the precalibrated Raman scattering gas monitor (Rascal, Albion Instruments, Salt Lake City, UT). Venous access was obtained for infusion of dextrose 2% in Ringer's lactate solution at a rate of 6 ml · kg<sup>-1</sup> · h<sup>-1</sup> after inhalation induction under a mask using oxygen and sevoflurane (3–4%). A Mapleson D system using a fresh gas flow of at least 200 ml · kg<sup>-1</sup> and Penlon vaporizer (PPV Σ<sup>60</sup>, Penlon, Abingdon, United Kingdom) were used.

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### MAC<sub>EI</sub> Determination

Anesthesia was induced *via* mask with sevoflurane and oxygen. After the ratio of alveolar to predetermined inspiratory concentration for sevoflurane had been maintained at greater than 0.95 for 15 min, laryngoscopy and tracheal intubation were attempted using an uncuffed tracheal tube and without neuromuscular relaxants or other adjuvants. Each concentration at which laryngoscopy and tracheal intubation were attempted was predetermined according to the up-and-down method (with 0.5% as a step size). A single measurement was obtained per patient. When tracheal intubation was accomplished without gross purposeful muscular movements, it was considered a smooth tracheal intubation. Coughing and bucking were considered purposeful. Patients who moved during laryngoscopy were immediately given 3–4% sevoflurane or an intravenous bolus dose of thiamylal (3 mg · kg<sup>-1</sup>) or succinylcholine (1 mg · kg<sup>-1</sup>). They were regarded as not having been intubated smoothly. Absence of any gross purposeful muscular movements was determined by unanimity of the anesthesiologist, surgeon, and nurse in charge of the case.

### MAC Determination

The patients examined were the same as those for MAC<sub>EI</sub> determination, but those who had been administered neuromuscular relaxants or other adjuvants were excluded from the study. End-tidal sevoflurane concentration was determined according to the up-and-down method (with 0.5% as a step size) and held constant for at least 15 min before the skin incision. After the skin incision the patients were observed for at least 1 min for signs of gross purposeful muscular movement. Twisting or jerking of the head was considered a purposeful movement, but not twitching or grimacing. Coughing, rigidity, swallowing, and chewing were not considered purposeful movements. Absence of any gross purposeful muscular movements was determined by unanimity of the anesthesiologist, surgeon, and nurse in charge of the case. A single measurement was obtained per patient. End-tidal sevoflurane and end-tidal carbon dioxide concentrations were measured continuously at the distal end of the tracheal tube. End-tidal carbon dioxide concentration was maintained at 30–35 mmHg during the study. Rectal temperature was maintained at 36–37° C.

Analyses of responses to intubation or skin incision were performed using a logistic model (SAS proprietary

software, Chicago, IL). A best-fitting sigmoid curve was depicted using maximum likelihood.

## Results

### MAC<sub>EI</sub> Determination

Thirty-six patients (17 boys and 19 girls) were enrolled in this study. Their ages ranged from 1 to 9 yr (mean age 4.6 yr). Their weight range was 9.7–28.0 kg. We excluded 1 patient, who was screaming before and after entering the operating room. The surgical procedures performed were plastic and reconstructive surgeries. Table 1 provides the end-tidal sevoflurane concentrations and percentages of patients who had no gross purposeful muscular movements. Curves constructed on the basis of logit analysis of responses from these patients (fig. 1) revealed that MAC<sub>EI</sub> of sevoflurane is 2.69% (95% fiducial limits: 2.23%, 3.37%).

### MAC Determination

Because we excluded 14 patients who had been given intravenous thiamylal or succinylcholine, 22 patients were enrolled in the study. Table 2 lists the end-tidal sevoflurane concentrations and percentages of patients who had no gross purposeful muscular movements. Curves constructed on the basis of logit analysis of responses from these patients (fig. 2) revealed that MAC is 2.03% (95% fiducial limits: 1.51% and 2.53%). The MAC<sub>EI</sub>/MAC ratio was 1.33 (MAC<sub>EI</sub> = 2.69%; MAC of sevoflurane = 2.03%).

No patient had dysrhythmia or bradycardia that necessitated any drug administration during the study.

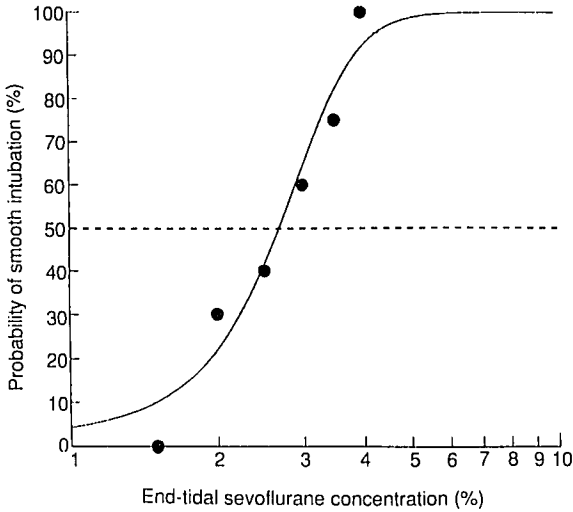
## Discussion

In the current study of patients aged 1–9 yr, the sevoflurane MAC<sub>EI</sub> was 2.69% and MAC 2.03% (MAC<sub>EI</sub>/MAC

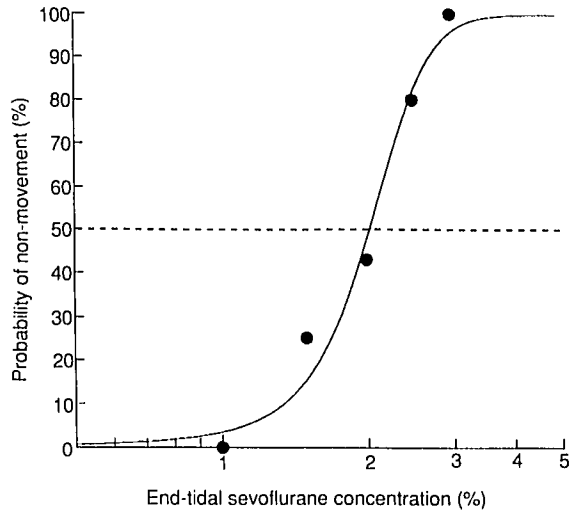
**Table 1. End-tidal Sevoflurane Concentration and Absence of Muscular Movements after Tracheal Intubation**

Number of Patients (n = 36)	End-tidal Sevoflurane Concentration (%)	No Gross Purposeful Movements (%)
4	1.5	0
10	2.0	30
10	2.5	40
5	3.0	60
4	3.5	75
3	4.0	100

MAC<sub>EI</sub> AND MAC OF SEVOFLURANE IN PEDIATRIC PATIENTS



**Fig. 1.** Dose-response curve for sevoflurane plotted from logit analyses of individual end-tidal concentrations and the respective reactions to tracheal intubation. Maximum likelihood solution the concentration at which probability of movement equaled 50% (MAC<sub>EI</sub>) is presented by the sigmoid curve. MAC<sub>EI</sub> is 2.69% (95% fiducial limits: 2.23% and 3.37%)



**Fig. 2.** Dose-response curve for sevoflurane plotted from logit analyses of individual end-tidal sevoflurane concentrations and their respective reactions to skin incision. Maximum likelihood solution for minimum alveolar concentration (MAC) is presented by the sigmoid curve. MAC is 2.03% (95% fiducial limits: 1.51% and 2.53%)

ratio = 1.33). These data agree reasonably well with MAC of sevoflurane of 1.71–2.05% in adults<sup>6,7</sup> and of 2.49% in pediatric patients aged 3–5 yr.<sup>8</sup> Furthermore, that MAC<sub>EI</sub> was approximately 30% greater than MAC agrees with previous data from Yakaitis *et al.*, who showed that MAC<sub>EI</sub> for enflurane and halothane in children 2–6 yr old was about 35% greater than the respective MAC values.<sup>4,5</sup>

In this study we used a Mapleson D anesthetic system and a sufficiently high fresh gas flow to reduce the likelihood of rebreathing.<sup>9</sup> Furthermore, we ensured that inhaled carbon dioxide was zero at the beginning of the inspiration. To reduce the possibility that the end-tidal gas concentration measured during ventilation *via* mask was not substantially contaminated by and thus

falsely increased by inspired gas, a 0.95 ratio of alveolar to predetermined inspiratory concentration was achieved and was maintained for 15 min. Therefore we assumed that the end-tidal sevoflurane concentration represents the sevoflurane concentration in the brain (arterial blood), and the end-tidal sevoflurane concentration was regarded as MAC<sub>EI</sub>.

In conclusion, MAC<sub>EI</sub> was 2.69% (95% fiducial limits: 2.23% and 3.37%); MAC of sevoflurane was 2.03% (95% fiducial limits: 1.51% and 2.53%); and the MAC<sub>EI</sub>/MAC ratio was 1.33. Sevoflurane appears to be suitable for use in pediatric patients as an induction agent, permitting tracheal intubation without muscle relaxants.

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**Table 2.** End-tidal Sevoflurane Concentration and Absence of Muscular Movements after Skin Incision

Number of Patients (n = 22)	End-tidal Sevoflurane Concentration (%)	No Gross Purposeful Movements (%)
3	1.0	0
4	1.5	25
7	2.0	43
5	2.5	80
3	3.0	100

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