The ED₉₅ of end-tidal sevoflurane concentration for the smooth exchange of the tracheal tube for a laryngeal mask airway is 2.97%

[La DE₉₅ de la concentration télé-expiratoire de sévoflurane nécessaire au remplacement sans à-coups du tube endotrachéal par un masque laryngé est de 2,97 %]

Koichi Takita MD, Masahiro Yamane MD, Yuji Morimoto MD PhD, Osamu Kemmotsu MD PhD

Purpose: Exchanging the tracheal tube for the laryngeal mask airway (the TT/LMA exchange) while the patient is still anesthetized avoids coughing associated with tracheal extubation. This study was conducted to determine the end-tidal concentration of sevoflurane that prevented response to this exchange in 50% patients (MAC_{TT/LMA}).

Methods: We studied 21 adult male patients, ASA I, aged 21–54 yr. Anesthesia was induced with thiamylal and sevoflurane, and the trachea was intubated following vecuronium neuromuscular blockade. Anesthesia was maintained with sevoflurane and nitrous oxide in oxygen. After surgery, a predetermined end-tidal sevoflurane concentration was achieved and a steady state was maintained for at least 20 min. The concentration at which the TT/LMA exchange was attempted was determined by a modification of Dixon's up-and-down method with 0.25% as the step size. At the time of the TT/LMA exchange, no residual nitrous oxide > 3% was detected, and the return to normal neuromuscular function was confirmed. When the TT/LMA exchange was accomplished without coughing, movement, or airway obstruction, it was considered a smooth exchange.

Results: Sevoflurane MAC_{TT/LMA} determined using the up-and-down method was 2.63% ± 0.14%. The 50% effective dose obtained using a probit analysis was similar [2.53% (95% confidence limits, 2.13–2.82%)].

Conclusion: Sevoflurane MAC_{TT/LMA} in adult male patients was 2.63% (1.54 MAC) and may be useful for the smooth exchange of the tracheal tube for the LMA in a clinical setting.

Objectif : Le remplacement du tube trachéal par le masque laryngé (TT/ML), alors que le patient est toujours anesthésié, prévient la toux associée à l'extubation trachéale. Notre étude a été réalisée pour déterminer la concentration télé-expiratoire de sévoflurane pouvant prévenir une réaction à l'échange précité chez 50 % des patients (CAM_{TT/ML}).

Méthode : Nous avons étudié 21 hommes d'état physique ASA I, de 21–54 ans. L'anesthésie a été induite avec du thiamylal et du sévoflurane et l'intubation a été réalisée à la suite du blocage neuromusculaire avec du vécuronium. L'anesthésie a été maintenue avec du sévoflurane et du protoxyde d'azote dans de l'oxygène. Après l'opération, une concentration de sévoflurane télé-expiratoire prédéterminée a été établie et l'état d'équilibre maintenu pendant au moins 20 min. La concentration à laquelle l'échange de TT/ML a été tenté était déterminée par une modification de la méthode de l'escalier de Dixon avec des paliers de 0,25 %. Au moment de l'échange, aucune trace de protoxyde d'azote résiduel > 3 % n'a été détectée et le retour de la fonction musculaire à la normale a été confirmé. L'échange de TT/ML réalisé sans toux, mouvement ou obstruction des voies aériennes était considéré comme régulier.

Résultats : La CAM_{TT/ML} de sévoflurane déterminée par la méthode de l'escalier a été de 2,63 % ± 0,14 %. La dose efficace à 50 % obtenue grâce à l'analyse par la méthode des probits a été similaire [2,53 % (limites de confiance de 95 %, 2,13–2,82 %)].

Conclusion : La CAM_{TT/ML} de sévoflurane a été de 2,63 % (CAM de 1,54) chez des patients adultes. Cette donnée pourrait servir en clinique à l'échange sans à-coups du tube endotrachéal pour le masque laryngé.

From the Department of Anesthesiology and Critical Care Medicine, Hokkaido University Graduate School of Medicine, Sapporo, Japan.

Address correspondence to: Dr. Koichi Takita, Department of Anesthesiology and Critical Care Medicine, Hokkaido University Graduate School of Medicine, Kita-15, Nishi-7, Kita-ku, Sapporo 060-8638, Japan. Phone: +81-11-706-7861; Fax: +81-11-706-7861; Email: ktakita@med.hokudai.ac.jp

Accepted for publication July 29, 2002.

Revision accepted November 6, 2002.

TRACHEAL extubation is often accompanied by coughing. Coughing can cause adverse effects, including an increase in intracranial and intraocular pressures, significant hemodynamic changes, and may threaten the surgical sites. One of the strategies to avoid coughing is tracheal extubation under deep anesthesia, followed by face-mask ventilation. This technique, however, increases the risk of airway obstruction after extubation. Recently, some authors reported that substitution of the laryngeal mask airway (LMA) for the tracheal tube while the patient is still anesthetized prevents the coughing associated with tracheal extubation, and provides a secure airway following tracheal extubation and a smooth recovery period.¹⁻⁵ Under light anesthesia, insertion of the LMA and tracheal extubation itself may cause coughing, movement, breath-holding, and/or laryngospasm. Thus, unless the TT/LMA exchange is attempted under adequate anesthesia, this method does not offer any advantage.

In the present study, we attempted to determine the sevoflurane $MAC_{TT/LMA}$ in adult male patients where sevoflurane $MAC_{TT/LMA}$ is the end-tidal concentration of sevoflurane at which a smooth exchange of the tracheal tube for the LMA was possible in 50% of patients.

Methods

After obtaining Institutional approval and informed consent, we studied 21 adult male patients, ASA physical status I, aged 21–54 yr, scheduled for general anesthesia for elective non-oral surgery. No premedication was used. Anesthesia was induced with thiamylal 5 mg·kg⁻¹ and sevoflurane, and the trachea was intubated orally with a regular cuffed tracheal tube (internal diameter 8.5-mm) following *iv* vecuronium 0.12 mg·kg⁻¹. If a patient presented difficult mask ventilation or difficult intubation, he was excluded from the study. Anesthesia was maintained with sevoflurane and nitrous oxide in oxygen. No other anesthetics were administered before the TT/LMA exchange. The patients were monitored with an electrocardiogram, a non-invasive arterial blood pressure monitor, a pulse oximeter, and a peripheral nerve stimulator applied to the ulnar nerve at the wrist (NS252 peripheral nerve stimulator, Fisher & Paykel Healthcare, Auckland, New Zealand). Breath-by-breath inspired/end-tidal sevoflurane, nitrous oxide and carbon dioxide concentrations were measured with a precalibrated gas monitor (M1026A anesthetic gas module, Philips Medical System Corporation, Best, The Netherlands). Inspired and end-tidal gases were sampled from the proximal end of the tracheal tube at a sampling flow rate of 120 mL·min⁻¹.

Accuracy of end-tidal measurements was confirmed by return of the end-tidal carbon dioxide trace to zero. A semiclosed circle system with a fresh gas flow of 6 L·min⁻¹ was used. Nitrous oxide was discontinued before the end of surgery. After surgery, a predetermined end-tidal sevoflurane concentration was achieved and a steady state maintained for at least 20 min to allow equilibration between the alveolar and brain concentrations. The concentration a particular patient received was determined by the response of the previous patient to a larger or smaller concentration (with 0.25% as a step size), using a modification of Dixon's up-and-down sequential method.⁶ At the time of the TT/LMA exchange, no residual nitrous oxide > 3% was detected in the end-tidal sample. Before the exchange, the return to normal neuromuscular function was confirmed with tactile evaluation of the responses of the adductor pollicis muscle to train-of-four stimulation. The airway was suctioned before a predetermined end-tidal sevoflurane concentration was achieved.

The TT/LMA exchange was attempted according to the method reported by Dob *et al.*¹ and Koga *et al.*² Before tracheal extubation, a deflated LMA was inserted while the tracheal tube was still in place. The lungs were inflated and the tracheal tube removed. The cuff of the LMA was then inflated, the breathing system was connected to the LMA, and adequacy of manual ventilation was confirmed. The size of LMA was determined by the manufacturer's weight-related recommendations by using size 4 for patients 50–70 kg and size 5 for patients more than 70 kg. The TT/LMA exchange was attempted by a Japanese Board certified anesthesiologist (K.T.) who has considerable experience with this technique. Patients' responses to the TT/LMA exchange, including coughing, gagging, and gross purposeful muscular movement were observed by an operating nurse and an anesthesiologist who were blinded to the sevoflurane concentration being tested. Airway obstruction immediately after the TT/LMA exchange was also regarded as a negative (adverse) response to the exchange. When the TT/LMA exchange was accomplished without any adverse response, it was considered a smooth exchange. The study protocol ended once it was determined whether the TT/LMA exchange was smooth or not. After completion of the study protocol, narcotics and/or nonsteroidal anti-inflammatory drugs for postoperative analgesia, in addition to antiemetics, were administered if necessary.

Patient demographics (age, body weight, body height, and body mass index), and duration of tracheal intubation are expressed as mean ± standard deviation (SD). We analyzed the value for $MAC_{TT/LMA}$ obtained

FIGURE 1 The responses of the 21 consecutive patients in whom the exchange of the tracheal tube for the laryngeal mask airway was attempted at different end-tidal concentrations of sevoflurane in oxygen. Individual patient data are represented by a circle. Arrows indicate the midpoint concentrations of all independent pairs of patients involving a cross-over; i.e., non-smooth exchange to smooth exchange. The minimum alveolar anesthetic concentration for exchanging the tracheal tube for the laryngeal mask airway at which a smooth exchange is possible in 50% patients was $2.63 \pm 0.14\%$ (mean $\pm$ SD).

by calculating the midpoint concentration of all independent pairs of patients involving a cross-over (i.e., non-smooth exchange to smooth exchange). $MAC_{TT/LMA}$ was defined as the average of the cross-over midpoints in each pair. $MAC_{TT/LMA}$ is expressed as mean $\pm$ SD. We also analyzed our data using a probit analysis (SPSS; SPSS Inc., Chicago, IL, USA) to obtain the probability of 50% (ED_{50}) and 95% (ED_{95}) smooth TT/LMA exchange *vs* end-tidal sevoflurane concentration, and 95% confidence limits.

Results

The age of the patients was 35.5 ± 12.0 yr; body weight was 59.1 ± 8.6 kg; body height was 166.7 ± 7.3 cm; and body mass index was 21.2 ± 2.0 $kg \cdot m^{-2}$. The duration of tracheal intubation was 182.6 ± 80.3 min. None of the patients presented difficult mask ventilation or difficult intubation. In all patients, the LMA was inserted on the first attempt while the tra-

cheal tube was still in place. No patient required repositioning of the LMA after the TT/LMA exchange. Sevoflurane $MAC_{TT/LMA}$ was $2.63 \pm 0.14\%$ (Figure 1). The dose-response curve constructed on the basis of probit analysis data in this patient population (Figure 2) showed that the ED_{50} and the ED_{95} of end-tidal sevoflurane concentration were 2.53% (95% confidence limits, 2.13–2.82%) and 2.97% (95% confidence limits, 2.73–6.16%), respectively. Maximum likelihood estimators of the probit model variables in this group showed a *P* value of 0.660 and a goodness of fit χ^2 of 1.597. Seven patients experienced coughing during insertion of the LMA, and five of them had airway obstruction immediately after the TT/LMA exchange. Three patients had airway obstruction without any other adverse response. These airway obstructions recovered within four minutes. No patient desaturated below 98% by pulse oximetry.

FIGURE 2 Dose-response curve for sevoflurane plotted from probit analyses of individual end-tidal concentrations and the respective patient reactions to the exchange of the tracheal tube for the laryngeal mask airway in this patient population. The concentrations at which there was a 50% and 95% probability of smooth exchange of the tracheal tube for the laryngeal mask airway were 2.53% and 2.97%, respectively.

Discussion

The current study showed that sevoflurane $MAC_{TT/LMA}$ was 2.63%. Given that the MAC value for sevoflurane in patients aged 30–59 yr has been reported to be 1.71%,⁷ the $MAC_{TT/LMA}/MAC$ ratio is 1.54. The ED_{95} of sevoflurane for smooth TT/LMA exchange was 2.97%, and the lower limit of the 95% confidence interval of the ED_{95} was 2.73%. This indicates that an end-tidal sevoflurane concentration of at least 2.73% (1.60 MAC) is required to ensure smooth TT/LMA exchange in most healthy adult male patients in the conditions of this study.

Use of the LMA after tracheal extubation under anesthesia provides suitable conditions for neurosurgical patients in terms of hemodynamic stability, avoidance of coughing, and airway maintenance.^{3–5} Dob *et al.* and Koga *et al.* also showed that substitution of the LMA for the tracheal tube decreases the incidence of

respiratory complications, including coughing and peripheral arterial oxygen desaturation during recovery from anesthesia, when compared with the use of a Guedel airway after extubation under deep anesthesia.^{1,2} Although TT/LMA exchange must be attempted under adequate anesthesia to suppress airway reflexes, the depth of anesthesia required for smooth TT/LMA exchange remains unclear. In previous reports, exchanges were performed while patients were still anesthetized and effectively paralyzed.^{1–5} These studies did not provide detailed information on the adequate depth of anesthesia for smooth TT/LMA exchange. $MAC_{TT/LMA}$ and ED_{95} values of sevoflurane determined in the present study may provide useful information for smooth TT/LMA exchange in the clinical setting. However, when the $MAC_{TT/LMA}$ and ED_{95} determined in the present study are applied to normal clinical practice, it should be taken into account that several factors, including the patient's age and the use of narcotics, affect the sevoflurane concentration required to ensure smooth TT/LMA exchange.

In the present study, anesthesia was induced with thiamylal 5 mg·kg⁻¹ and vecuronium 0.12 mg·kg⁻¹ was used to facilitate tracheal intubation. However, it is likely that these agents had little influence on the determination of sevoflurane $MAC_{TT/LMA}$. This is because the TT/LMA exchange was attempted more than 70 min after the administration of thiamylal, an induction dose of which has an effective duration of about five to eight minutes,⁸ and the return to normal neuromuscular function was confirmed before the exchange.

The technique of TT/LMA exchange is composed of insertion of the LMA and tracheal extubation. Previous investigations have shown that the end-tidal concentrations of sevoflurane to prevent response to insertion of the LMA in 50% of patients (MAC_{LMA}) and to prevent response to tracheal extubation (MAC_{EX}) are 2.00% and 1.07%, respectively.^{9,10} It is unclear why the TT/LMA exchange requires a higher end-tidal concentration of sevoflurane than do the individual procedures taken separately. In the present study, insertion of the LMA was attempted before tracheal extubation. This method can avoid the risk of compromising the airway if insertion of the LMA were impossible, though this technique does not always guarantee maintenance of the airway after tracheal extubation. Using this sequence, insertion of the LMA stimulates the trachea and the vocal cords via the movement of the tracheal tube, in addition to the stimulation of the upper airway caused by the LMA itself. This may explain why a TT/LMA exchange requires higher end-tidal concentration of sevoflurane.

In conclusion, sevoflurane $MAC_{TT/LMA}$ and ED_{95} values of end-tidal sevoflurane concentration for smooth TT/LMA exchange are 2.63% and 2.97%, respectively. The $MAC_{TT/LMA}$ and ED_{95} values of sevoflurane determined in the present study may be useful for smooth TT/LMA exchange in the clinical setting.

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