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Original Contribution

Determination of insertion depth of flexible laryngeal mask airway in pediatric population—A prospective observational study☆

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ABSTRACT

Study objective: The purpose of this study was to determine the ideal insertion depth of the flexible laryngeal mask airway (FLMA) by elucidating the relationships between insertion depth and patient's age, body weight, height, and other parameters. We also evaluated an insertion technique that uses the change in intracuff pressure for proper positioning of the FLMA in cases where it is difficult to sense resistance during FLMA insertion.
Design: This study was a prospective observational study.
Setting: Participants were recruited from the Seoul National University Children's Hospital.
Patients: We enrolled 154 children aged ≤15 years with an American Society of Anesthesiologists physical status of I or II who were scheduled for ophthalmic surgery of <2 hours duration under general anesthesia.
Interventions: After induction of general anesthesia, FLMA insertion was guided by the change in intracuff pressure, measured using a manometer. The FLMA position was assessed using a fiberoptic bronchoscope.
Measurements: The FLMA insertion depth was measured at the end of each surgical procedure. A multiple linear regression model was then created using age, height, weight, nasal-tragus length, and sternal length.
Main results: The FLMA was successfully inserted in the first attempt in 134 patients using continuous monitoring of intracuff pressure. Using multiple linear regression analysis and the Durbin-Watson test, we found that insertion depth was best predicted by height and weight ($r^2 = 0.777$), and the resulting formula was as follows: insertion depth of FLMA (cm) = 7.0 + 0.04×height (cm) + 0.05 ×weight (kg).
Conclusions: The FLMA insertion depth can be calculated using height and weight. Continuous monitoring of intracuff pressure during FLMA insertion is a useful alternative insertion method in cases where resistance is difficult to sense.

1. Introduction

The laryngeal mask airway (LMA) is an extraglottic airway device that is widely used for emergency situations and anesthetic management. Several types of LMAs are available. The flexible LMA (FLMA) (LMA Flexible; LMA North America, San Diego, CA) was developed to prevent interference in the surgical field [1] and is especially useful for surgery near or involving the face [2-5].

The insertion technique for the FLMA is identical to that for the standard LMA [1]. Clinicians commonly advance the LMA until resistance is felt, and then fix the LMA in place. The LMA is properly positioned when its tip is located posterior to the cricoid cartilage and engages the upper esophageal sphincter (UES) [6]. Proper positioning of the LMA in children is not always easy with this standard method because of the unique airway anatomy of children, such as a relatively large tongue, higher and more anterior larynx, large, flaccid epiglottis, and presence of tonsillar hypertrophy [7]. In addition, a clear sensation of resistance at the proximal esophagus is often difficult to detect, especially in anesthetized and young patients [8,9]. An unclear sensation of resistance results in advancement of the LMA past the proper position, causing airway obstruction. The FLMA has a long, nonrigid flexometallic tube without a bite block or length indicator, making its positioning difficult [3].

Establishment of a method to estimate insertion depth of the FLMA using a centimeter-marked tube could serve as a guideline for positioning the FLMA in cases of unclear resistance during insertion. The purpose of this study was to determine FLMA insertion depth by examining the relationships between insertion depth and age, body weight, height, and other parameters. We also evaluated an alternative

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FLMA insertion technique that relies on the monitoring of intracuff pressure for proper positioning of the FLMA.

2. Materials and methods

This study was approved by the institutional review board (H-1206-068-414, Seoul, Korea; chairperson Prof BJ Park) of Seoul National University Hospital and registered at http://cris.nih.go.kr (KCT0001160). The study was performed according to the World Medical Association's Declaration of Helsinki.

Written informed consent was obtained from all patients or their guardians. In total, 154 children aged 15 years or younger with an American Society of Anesthesiologists physical status of I or II who were scheduled for ophthalmic surgery of less than 2 hours in duration under general anesthesia were enrolled. Patients were excluded who had a risk of pulmonary aspiration, any pathology of the airway or alimentary tract, or markedly loose teeth.

2.1. Anesthetic management

Patients were not premedicated. Appropriate monitoring of each patient was performed in the operating room, and 100% oxygen was administered. After administration of atropine (0.02 mg/kg), anesthesia was induced with 5 mg/kg of intravenous thiopental sodium. After ensuring adequate mask ventilation, rocuronium (0.6 mg/kg) was administered to facilitate airway instrumentation. Manual ventilation was performed with 4-8 vol% sevoflurane in 100% oxygen using a facemask. After muscle relaxation was confirmed by single-twitch response, the FLMA was inserted. Anesthesia was maintained with 6-8 vol% desflurane, and the FLMA was removed at the end of surgery. The children were transferred to a postanesthetic care unit after full recovery from anesthesia.

2.2. Determination of insertion length of FLMA

Before insertion of the FLMA, a plain endotracheal tube (inner diameter, 3.5 mm), the cuff of which was previously inflated with a pressure gauge to 10 cmH_2O, was smoothly inserted through the oral cavity to the hypopharynx until the cuff pressure suddenly increased to >10 cmH_2O. Assuming that the distal tip of the endotracheal tube was then located at the UES, the length between the distal part of the cuff and the upper incisors (endotracheal tube length [ETL]) was measured.

After removal of the endotracheal tube, the FLMA was prepared according to the patient's weight as specified by the manufacturer's guidelines, which suggest size 2 for 10- to 20-kg patients, size 2.5 for 20- to 30-kg patients, and size 3 for 30- to 50-kg patients. After application of water-soluble lubricant, the FLMA was inserted with the cuff partially inflated until the intracuff pressure was 10 cmH_2O. An assistant kept the patient's head slightly extended, jaw thrust, and mouth opened during insertion. The FLMA was inserted with the tube held lightly using the index finger and thumb, a technique that differs from the standard method in which the FLMA is held like a pen and inserted using the index finger until resistance is felt [10]. The cuff pressure was continuously monitored using a manometer during the insertion of the FLMA. When the FLMA passes the hard palate and oropharynx, the intracuff pressure increased to >20 cmH_2O temporarily due to pressure on the hard palate and the posterior pharyngeal wall. When the tip of the cuff was positioned in the laryngopharynx, which is below the epiglottis, the intracuff pressure abruptly decreased. Finally, the tip of the cuff entered the esophageal inlet, the intracuff pressure increased again to >10 cmH_2O, and the FLMA was fixed at the midline. All FLMAs were inserted by an experienced pediatric anesthesiologist (LJH) who had performed more than 200 FLMA insertions and more than 300 insertions of other LMA types in children during the preceding year.

Appropriate placement of the FLMA was confirmed by adequate chest movement, an end-tidal carbon dioxide waveform by gentle squeezing of the reservoir bag, and adequate oropharyngeal leak pressure greater than 15 cmH_2O [11]. When a change in cuff pressure was not observed with the manometer during the first insertion attempt, the FLMA was removed and inserted using the standard method, and the patient was then excluded from the study.

After FLMA insertion using the cuff pressure change and subsequent fixation, the position of the FLMA was measured using a fiberoptic bronchoscope in 20 patients who were chosen randomly, and the airways of these patients were assessed for visible structures, which were categorized as vocal cords, epiglottis, posterior commissural, and none [12]. Finally, both the sternal length (STL), a distance between the sternal notch and the xiphoid process, and the nasal-tragus length (NTL) were measured in all patients.

There are possible FLMA-related complications, such as relocation of the larynx during the surgery, making ventilation difficult, laryngopharyngeal pain, frenulum injury, and gastric content aspiration. All complications were managed according to standard protocol. If the FLMA was dislocated during the surgery, it was repositioned by several techniques, such as placing a roll beneath the shoulder, positioning the patient's head to a more extended position, or increasing the anesthetic depth. If adequate ventilation was not achieved using these techniques, the FLMA was removed and mask ventilation was performed before reinsertion of the FLMA or intubation. Each manipulation was performed gently to avoid laryngopharyngeal pain and frenulum injury.

The insertion depth of the FLMA from the tip of the FLMA to the shaft at the level of the lip angle was measured after removal of the FLMA.

2.3. Statistical analysis

Statistical analyses were performed using SPSS version 20 (SPSS Inc, Chicago, IL). A linear regression model was used to determine the relationships between the insertion depth achieved by cuff pressure changes and patient's age, height, weight, STL, and NTL. We used preliminary data for sample size calculation. When the linear regression analysis was performed using NTL and insertion depth of the FLMA, the correlation coefficient and slope were 0.23 and 0.239, respectively. Using these values, the sample size we needed for statistical significance with an α of .05 and a power of 0.8 was 143. With an estimated 8% drop-out rate, we decided to include 154 patients in this trial.

The differences between the ETL and insertion depth and other parameters were compared using independent sample *t* tests to assess the accuracy of the insertion depth. Data are presented as mean ± SD (range). A *P* value of <.05 was considered to indicate statistical significance.

3. Results

In total, 154 pediatric patients were enrolled in this study. Among these, the FLMA was successfully inserted using intracuff pressure change on the first attempt in 134 patients, whereas the FLMA was inserted using a standard technique in the remaining 20 patients because of failure to detect the cuff pressure change by manometer. Therefore, data from 134 patients were analyzed. No patients had facial

Table 1
Baseline characteristics and outcomes of the patients.

	By cuff pressure change (n = 134)
Age (y)	5.0 (2.5)
Sex (M/F)	65/69
Height (cm)	110.1 (17.3)
Weight (kg)	20.5 (8.6)
FLMA no (2/2.5/3/4)	92/32/8/2
Mean airway pressure during anesthesia (cmH_2O)	13.6 (3.6)

Values are presented as mean (SD) or number.