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Lower intracuff pressure of laryngeal mask airway in the lateral and prone positions compared with that in the supine position

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Abstract
We compared the intracuff pressure (ICP) of a laryngeal mask airway (LMA) in the lateral and prone positions with that in the supine position. One hundred and eight patients, weighing 50–70 kg, scheduled for elective orthopedic and plastic surgery, were assigned to three groups, based on their body position during surgery. General anesthesia was induced and then a size 4 deflated LMA was inserted in each patient in the supine (group 1; $n = 42$), lateral (group 2; $n = 45$), or prone position (group 3; $n = 21$). The LMA cuff was inflated with 15 ml of air. Anesthesia was maintained without nitrous oxide, and the ICP was measured until LMA removal in the supine position. ICP in groups 2 and 3 was significantly lower than that in group 1 from immediately after insertion to the end of surgery. After surgery, turning from the lateral (group 2) or prone (group 3) position to the supine position significantly raised the ICP. Because the ICP is related to the seal pressure of the LMA and postoperative pharyngolaryngeal morbidity, we recommend evaluating and adjusting the ICP appropriately in each body position.

Key words Cuff · Flexible · Pharyngolaryngeal morbidity · Positional change · Seal pressure

Introduction

The laryngeal mask airway (LMA) is effectively and safely used for surgical patients in the lateral and prone positions, as well as the supine position [1–5]. The LMA is inserted with the patient in the supine position and then patients are moved into the lateral or prone position, or it is inserted with the patient in the lateral or prone position. The benefit of the latter procedure would be to reduce the risk of injuries to patients and to save time and staff involved in moving the patient into the new position. Because the upper airway is dilated in the lateral and prone positions, probably due to gravitational changes in the geometry of pharyngeal tissues surrounding the LMA cuff [6–9], these positions may influence the intracuff pressure (ICP). To date, however, variations of the ICP in different body positions remain unknown. The ICP is a factor in the incidence of postoperative pharyngolaryngeal discomfort [10,11] and it is related to pharyngeal seal with the cuff in the supine position [12,13]. For airway management with the LMA, it would be valuable to ascertain the effects of body position on the ICP. In this study, we inserted the LMA in patients in the supine, lateral, or prone position and compared the ICP among these positions in anesthetized, nonparalyzed, mechanically ventilated patients.

Patients and methods

After obtaining the approval of our Hospital Ethics Committee and informed patient consent, we studied 108 consecutive patients, weighing 50 to 70 kg undergoing elective orthopedic or plastic surgery. These patients were classified as American Society of Anesthiologists (ASA) physical status I to III, and did not have known or predicted difficult airways, mouth-opening problems, cervical spine disease, or risk of aspiration of gastric contents. They were assigned to three groups based on the body position during surgery. The types of surgery and positions were: total knee arthroplasty (group 1; $n = 42$; supine) arthroscopic shoulder surgery (group 2; $n = 45$; lateral), and repair of Achilles' tendons or minor plastic surgery on the back (group 3; $n = 21$; prone). Both the LMA insertion and the surgery were performed in the supine, lateral, and prone positions in groups 1, 2, and 3, respectively.

A flexible LMA (LMA Flexible; The Laryngeal Mask Company, Oxon, UK) was used, and size 4 was chosen

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Table 1. Demographic data

	Group 1	Group 2	Group 3	*P* value
n	42	45	21	
Age (years)	73 (58–82)	59 (21–75)[1]*	53 (18–78)[1]*	<0.001
Male/female	7/35	30/16[1]*	10/11[3]*	<0.001
Weight (kg)	58 (50–70)	60 (50–70)	63 (50–70)	>0.05
Height (cm)	150 (146–169)	161 (146–175)[1]*	163 (150–185)[1]*	<0.001
Body mass index (kg/m^2)	25 (21–34)	23 (17–30)[2]*	23 (18–30)[3]*	<0.001
Anesthesia				
General alone/General plus epidural ropivacaine 0.25%	2/40	45/0[1]*	21/0[1]*	<0.001
Duration of anesthesia (min)	142 (96–263)	131 (66–209)[3]*	75 (57–137)[1]*[4]*	<0.001

[1]* $P < 0.001$; [2]* $P < 0.01$; [3]* $P < 0.05$ versus group 1; [4]* $P < 0.001$ versus group 2
Data values are presented as numbers or medians (ranges)

for patients of body weight 50 to 70 kg, according to the manufacturer's instructions. The LMA cuff was fully deflated, then lubricated with a water-based lubricant (K-Y Lubricating Jelly; Johnson and Johnson, Maidenhead, UK) on the posterior aspect in preparation. Patients from groups 1, 2, and 3 were placed on the operating table in the supine, lateral, and prone positions, respectively, with the head and neck in the neutral position, except for those in the prone position, in whom the head was rotated to the left. Perioperative monitoring included pulse oximetry, capnography, electrocardiography, noninvasive blood pressure measurement, and bispectral index (BIS). BIS values were obtained with an Aspect BIS Monitor (Model A-2000; Aspect Medical Systems, Natick, MA, USA). After preoxygenation with a face mask, patients received either 2 $\mu g \cdot kg^{-1}$ fentanyl or 1 $\mu g \cdot kg^{-1}$ remifentanil, followed by 2.5 $mg \cdot kg^{-1}$ propofol, and ventilation was controlled via the face mask during the induction phase. The LMA was then inserted by a single skilled user (~500 cases a year), using the midline approach of the standard technique, which included placement of the cuff flat against the hard palate, and advancing the cuff along the posterior palatopharyngeal curve with the index finger [14]. The LMA cuff was inflated with 15 ml of air. A cuff pressure manometer (Mallinckrodt, Sulz, Germany) was connected to the pilot balloon of the cuff immediately after LMA insertion, and the ICP was continuously monitored until LMA removal. Anesthesia was maintained by continuous infusion of propofol and either additional boluses of fentanyl, targeting 2 $ng \cdot ml^{-1}$ of predicted effect-site concentration by pharmacokinetic simulation, or continuous infusion of remifentanil at a rate of 0.2–0.5 $\mu g \cdot kg^{-1} \cdot min^{-1}$; BIS values were kept in the 40-to-50 range until the last ICP measurement. Forty of the 42 patients in group 1 received continuous epidural infusion of 0.25% ropivacaine combined with general anesthesia (see Table 1). During the maintenance phase, the patients were principally under pressure-controlled ventilation with a mixture of air and oxygen ($F_{I_{O_2}}$, 0.4) at a fresh gas flow of 2 $l \cdot min^{-1}$ to maintain Pa_{CO_2} between 35 and 40 mmHg. Nitrous oxide was not used throughout this study because it is much more permeable to the silicone-based cuff of the LMA than oxygen and nitrogen [15] and increases the ICP until equilibrium is reached [16]. The ICP readings were recorded immediately after LMA insertion, at the initiation of the surgery, every 30 min subsequently, and at the end of the surgery, in all groups. After the end of surgery, patients in groups 2 and 3 were turned to the supine position and the ICP was measured immediately before and after the positional change. The LMA was removed in the supine position in all groups after emergence from anesthesia.

Nominal data were analyzed by χ^2 test for independence. Continuous data were analyzed using either the Wilcoxon matched-pairs signed-ranks test or the Kruskal-Wallis test followed by the Steel-Dwass multiple comparison procedure, because the data were nonnormally distributed. Data values are presented as numbers or medians (ranges). *P* values of less than 0.05 were considered significant.

Results

Demographic data are shown in Table 1. Patient characteristics, except for body weight, were significantly different among the groups. The durations of anesthesia also differed.

The ICP values in different body positions are demonstrated in Fig. 1. The initial ICP immediately after LMA insertion in the lateral (18 cmH_2O; range, 6–48 cmH_2O) and prone positions (18 cmH_2O; range, 4–32 cmH_2O) was significantly lower than that in the supine position (34.5 cmH_2O; range, 16–72 cmH_2O; $P < 0.001$; Fig. 1A). During surgery, the highest ICP in the lateral (20 cmH_2O; range, 7–48 cmH_2O) and prone posi-

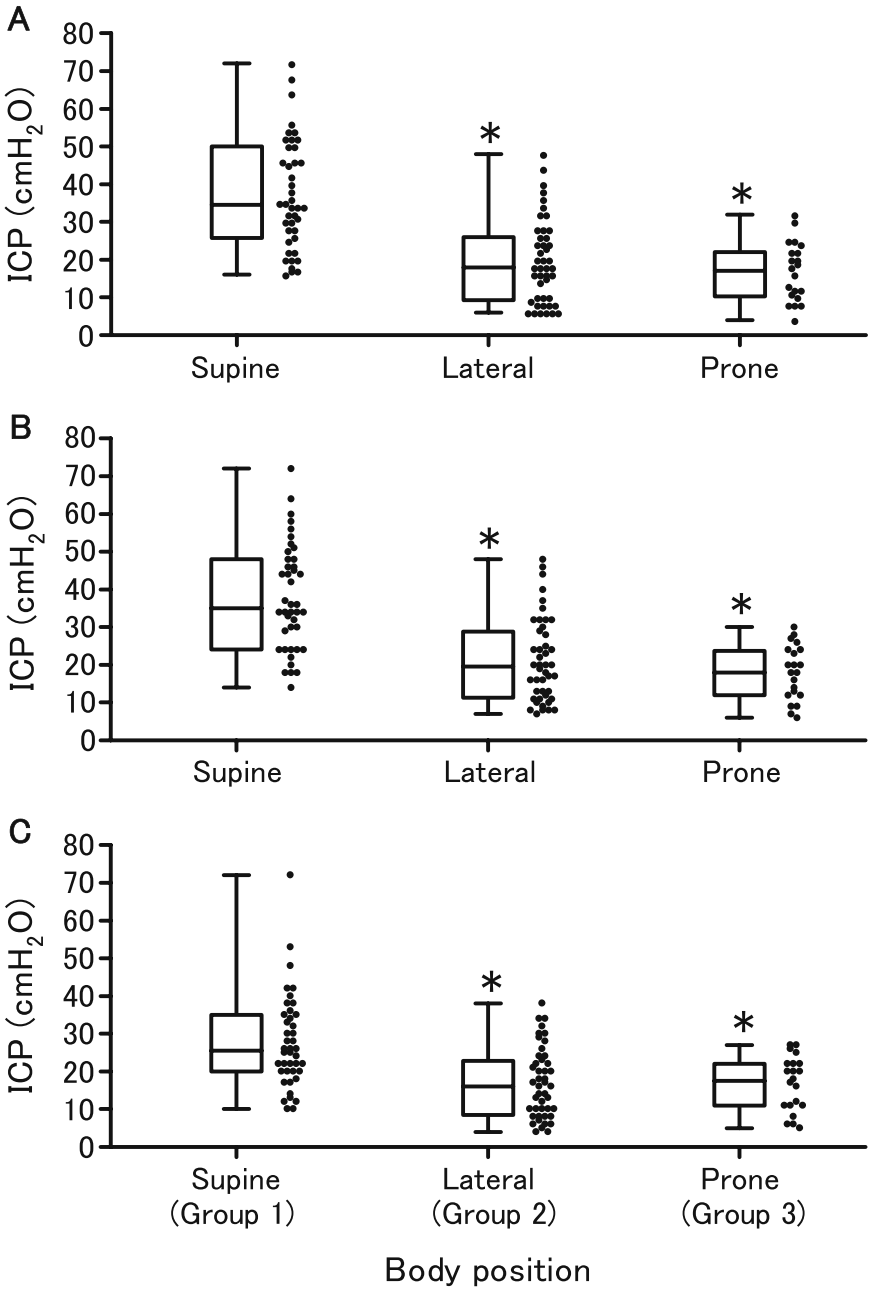

Fig. 1A–C. Intracuff pressure (*ICP*) of the laryngeal mask airway in different body positions. Patients in groups 1, 2, and 3 were placed in the supine, lateral, and prone positions, respectively. **A** ICP immediately after insertion. **B** Highest ICP during surgery. **C** Lowest ICP during surgery. *Each dot* depicts the value for an individual patient. *Boxes* depict median values and quartile ranges, and *vertical bars* show ranges. * $P < 0.001$ versus the supine position

tions (18 cmH_2O; range, 6–30 cmH_2O) was lower than that in the supine position (35 cmH_2O; range, 14–72 cmH_2O; $P < 0.001$; Fig. 1B). Also, the lowest ICP during surgery was lower in the lateral (16 cmH_2O; range, 4–38 cmH_2O) and prone positions (18 cmH_2O; range, 5–27 cmH_2O) than that in the supine position (25.5 cmH_2O; range, 10–72 cmH_2O; $P < 0.001$; Fig. 1C).

The effect of positional change on the ICP is shown in Fig. 2. All ICP values in groups 2 and 3 increased after positional change ($\Delta ICP > 0$, see Fig. 2). ICP in the supine position (32 cmH_2O; range, 10–66 cmH_2O) was significantly higher than that in the lateral position (17 cmH_2O; range, 4–44 cmH_2O) in group 2 ($P < 0.001$; Fig. 2A), and that in the supine position (28 cmH_2O; range, 16–44 cmH_2O) was significantly higher than that in the prone position (18.5 cmH_2O; range, 5–27 cmH_2O) in group 3 ($P < 0.001$; Fig. 2B).

Discussion

The LMA is widely used in both the lateral and the prone positions [1–5]; however, it remains unclear whether these positions have an impact upon the ICP. This is the first report of the differences in ICP between

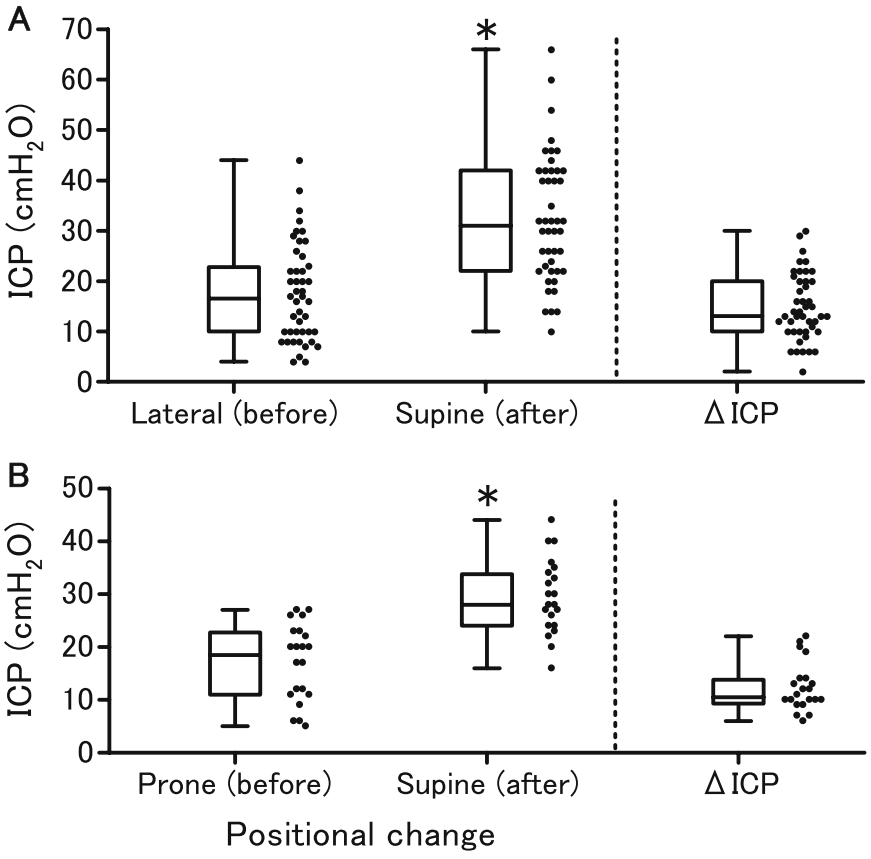

Fig. 2A,B. Effect of positional change on the intracuff pressure (*ICP*) of the laryngeal mask airway. **A** Turning from the lateral position to the supine position in group 2. **B** Turning from the prone position to the supine position in group 3. ΔICP equals ICP after positional change minus ICP before positional change. *Each dot* depicts the value for an individual patient. *Boxes* depict median values and quartile ranges, and *vertical bars* show ranges. $*P < 0.001$ versus before positional change

the supine, lateral, and prone positions when cuff volume is equal in all subjects and virtually constant. ICP in the lateral and prone positions was lower than that in the supine position when the LMA was inserted in these positions. Also, positional change from the lateral or prone position to the supine position raised ICP. Keller et al. [12] found that a mean cuff volume of 15 ml for a size 4 LMA fulfilled both the best seal pressure and ICP within the limit of 60 cmH_2O. Accordingly, a cuff volume of 15 ml was adopted for the size 4 flexible LMA in our study. When the LMA is ideally positioned in the pharynx, the LMA cuff faces the upper esophageal sphincter, the pyriform fossae, the base of the tongue, the posterior pharyngeal wall, and the aryepiglottic folds [17]. Forces from these tissues would vary among body positions due to the differing gravitational vectors [7,9]. Particularly in the lateral and prone positions, the tongue falling over the proximal cuff would be displaced in the direction of gravity [6,7] and would press the cuff to a lesser extent, thereby lowering the ICP. Furthermore, the rotated head and neck in the prone position may modify ICP due to pharyngeal compression or decompression. It has been shown that a high ICP causes postoperative pharyngolaryngeal morbidity [10,11] and ICP with an increasing cuff volume is correlated with seal pressure with the respiratory tract, which peaks at around one-third to two-thirds of the maximum recommended cuff volume in the supine position [12,13]. Changes in ICP due to different body positions may have an effect on pharyngolaryngeal morbidity and seal pressure, which have been defined in the supine position.

Our study has some limitations. First, the study was not randomized. Demographic data differed among the groups because each group was characterized by the surgical procedure. It cannot be denied that differences in sex, age, height, and body mass index impacted on our results to some degree, because there are no data directly addressing this issue. The duration of anesthesia actually seems not to be critical, because nitrous oxide was not used. Second, the pharyngeal muscle tone may have influenced the ICP, though, throughout the trial, patients were provided with an adequate depth of anesthesia, to minimize muscle tone [18], and they were mechanically ventilated, because spontaneous respiration produces a change in ICP [19]. Third, there was a possibility of differences in cuff positions of the LMA between the groups. A fiberoptic view of the glottis represents the anatomic cuff position, but does not always reflect the degree of functional seal of the cuff [20,21]. The influence of cuff position on our results is not known. Fourth, the study was not blinded. Though

subjective outcomes were not included in our results, bias could not be avoided to a certain extent.

In conclusion, we suggest that the ICP of an LMA in the lateral and prone positions is lower than that in the supine position, and positional change between the lateral/prone position and the supine position causes variation of the ICP. To get the best seal pressure and to avoid pharyngolaryngeal morbidity, we recommend evaluating and adjusting the ICP appropriately if necessary in each position, especially after positional change. This study provides a basis for a randomized controlled study to elucidate the relation of body position to ICP, seal pressure, and pharyngolaryngeal morbidity with the LMA.

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