A Comparison of Airway Sealing Pressure and Positioning of Three Types of Laryngeal Mask Airway

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Abstract: Three types of laryngeal mask airway (LMA) are commercially available and include the standard laryngeal mask airway (sLMA), flexible laryngeal mask airway (fLMA), and intubating laryngeal mask airway (iLMA). The three types of LMA are a similar shape and are comprised of almost identical materials apart from the tubing. Differences in tubing construction between the three types of LMA result in differences in physical characteristics. In the present study, the oropharyngeal leak pressure and fiberoptic bronchoscopy score of the three types of LMA was investigated in 20 patients. Patients were fitted with each type of LMA alternately in random order. The position of the LMA was observed using the following fiberoptic scoring system: 4, only vocal cords visible; 3, vocal cords plus posterior epiglottis visible; 2, vocal cords plus anterior epiglottis visible; 1, vocal cords not seen. Oropharyngeal leak pressure was measured in two body positions: the frontal position, with the face pointed forward and tilted upward, and the tilted position, with the head turned 45 degrees to the right. In both body positions, the number of patients with the highest fiberoptic score of 4 was significantly greater for the iLMA than for the sLMA or fLMA (p < 0.05). The oropharyngeal leak pressure was significantly higher for the iLMA than for the sLMA or fLMA (p < 0.05). The alterations in oropharyngeal leak pressure were smaller after changing body position for the iLMA than for the sLMA or fLMA. There was no significant correlation between fiberoptic score and oropharyngeal leak pressure for any LMA, except for the fLMA in the frontal position (p < 0.05). The differences in oropharyngeal leak pressure and fiberoptic score between the three types of LMA investigated in the present study result from the properties of the LMA tube as the other mask characteristics are similar. The material and shape of the LMA tubing should be carefully considered to maximize oropharyngeal leak pressure.

Key words: equipment laryngeal mask airway, monitoring oropharyngeal leak pressure, fiberoptic positioning

Introduction

When a laryngeal mask airway (LMA) is fitted to a patient it is important to ensure adequate airway sealing of the LMA against the surrounding tissue. Air tightness is deter-
mined by measuring oropharyngeal leak pressure during positive pressure ventilation. An oropharyngeal leak pressure of less than 10 cm H2O makes it difficult to perform appropriate artificial ventilation and increases the risk of regurgitation. Airway sealing pressure is greatly influenced by positioning and recent studies have shown that oropharyngeal leak pressure varies according to LMA size and intracuff pressure.

Various types of LMA are available other than the standard LMA (sLMA) developed by Brain et al. The flexible LMA (fLMA) is used for oral surgery and has a tube with a spiral metal wire indwelled in the tube wall. The intubating LMA (iLMA) is used for patients in whom tracheal intubation is difficult. The iLMA has an epiglottis elevating bar instead of a slit at the center of the mask. The three types of LMA are a similar shape and are comprised of almost identical materials apart from the tubing. The silicone tube of the sLMA allows external forces to be absorbed. By comparison, the tube of the iLMA is comprised of a more rigid construction of silicone-covered metal such that external forces directly influence positioning. The tubing of the iLMA is highly flexible due to the spiral metal wire indwelled in the silicon tube wall and the small diameter of the tubing, which is smaller than the tubing used for the sLMA and iLMA. Keller and Brimacombe reported a higher sealing pressure for the iLMA than for the sLMA and hypothesize that the sealing pressure influences positioning and sealing. There are no reports investigating positioning and airway sealing of the three types of LMA. The aim of the present study was to examine the characteristics of LMA tubing on fiberoptic positioning and airway sealing pressure.

**Methods**

The Local Ethics Committee approved the study and informed consent was obtained from patients. The subjects were 20 patients (12 males and 8 females) ranging in age from 20 to 67 years (average: 47±17 years), who were scheduled for elective surgery at Tokyo Rosai Hospital from April 2001 to March 2002. After administering 2-3 mg/kg of propofol and 0.12 mg/kg of vecuronium bromide, Brain’s insertion method was used to insert a size 4 LMA for males and a size 3 LMA for females. These procedures were performed by an anesthesiologist with more than 10 years of experience in the insertion of LMAs. Each type of LMA was used sequentially in random order in each patient. After insertion of each LMA, the cuff was inflated to maintain an intracuff pressure of 60 cm H2O to maximize airway sealing pressure. Artificial ventilation was performed with 100% oxygen and anesthesia was maintained with propofol at 8 mg/kg/h until the scheduled testing was complete.

After positioning each LMA, artificial ventilation was continued for 3 minutes, then a fiberoptic bronchoscope (external diameter: 5 mm) was inserted through the tube to a level 5 mm past the slit or epiglottis elevating bar. The position of the fiberoptic bronchoscope was determined using the following scoring system: 4, only vocal cords visible; 3, vocal cords plus posterior epiglottis visible; 2, vocal cords plus anterior epiglottis visible; 1, vocal cords not seen. The oropharyngeal leak pressure was determined by closing the expiratory valve of the circle system at a fixed gas flow of 3 L/min and measuring the airway pressure at which the dial on the aneroid manometer reached equilibrium.

For each patient, the fiberoptic score and oropharyngeal leak pressure of each LMA was determined in random order for both body positions: with the face pointed forward and head tilted upward (frontal position) and with the head turned 45 degrees to the right.
(tilted position). Each LMA was removed immediately after obtaining the above data and replaced with an untested LMA for continuation of measurements as described above. In cases when the iLMA was the final tested LMA, it was replaced with the sLMA to avoid damage by sustaining the iLMA.

Statistical comparisons of oropharyngeal leak pressure were performed using one-way analysis of variance (ANOVA) and Turkey-Kramer HSD. The chi-square test was used to compare the fiberoptic scores for the three-groups and for correlations between fiberoptic scores and oropharyngeal leak pressure. AP value less than 0.05 was considered statistically significant.

**Results**

In all subject cases (Table 1), each LMA was smoothly inserted on the first or second attempt and adequate ventilation was assessed by observing chest expansion and auscultation of the chest during positive pressure ventilation. There were no symptoms of hypoxemia or hypercapnia during the surgery. Although 7 of the 20 patients complained of a slight sore throat 24 hours after surgery, no patient had sustained soreness after 72 hours.

**Scores**

The score distribution for each type of LMA is shown in Fig. 1. In both body positions, the number of patients with the highest score of 4 was significantly higher for the iLMA (50% of the patients in the tilted position and 40% in the frontal position) than for the sLMA or fLMA (p < 0.05). By comparison, the likelihood of the lowest score of 1 was highest for the fLMA, regardless of body position. Adequate artificial ventilation was performed for all patients, including those with a score of 1. There was no significant difference in score between the two body positions for all three types of LMA. The total number of patients with a score of 3 and 4 was the same, regardless of body position, for all LMAs: 11 patients for the iLMA, 5 for the sLMA, and 3 for the fLMA.

**Oropharyngeal leak pressure**

Table 2 summarizes the oropharyngeal leak pressure measurements for all three LMA types in both body positions. The oropharyngeal leak pressure was significantly higher for the iLMA than for the sLMA or fLMA in both body positions (p < 0.05). The average oropharyngeal leak pressure was 2.2 cm H2O higher in the tilted position than in the frontal position for the sLMA, but this difference was not significant. The average oropharyngeal leak pressure for the iLMA and fLMA in both body positions was comparable.

Fig. 2 shows changes in oropharyngeal leak pressure between the two body positions of the same patient. The difference of oropharyngeal leak pressure between the frontal
Fig. 1. Score distribution for each type of LMA
In both body positions, the number of patients with the highest score of 4 was significantly higher for the fLMA than for the sLMA or fLMA (p<0.05).

- 4: Only vocal cords visible
- 3: Vocal cords plus posterior epiglottis visible
- 2: Vocal cords plus anterior epiglottis visible
- 1: Vocal cords not seen

Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Oropharyngeal Leak Pressure (cmH₂O)</th>
<th>Mean ± SD</th>
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<tbody>
<tr>
<td></td>
<td>standard LMA</td>
<td>flexible LMA</td>
</tr>
<tr>
<td>facing up</td>
<td>14.5±4.9</td>
<td>15.0±4.4</td>
</tr>
<tr>
<td>tilting right</td>
<td>16.7±6.1</td>
<td>15.3±4.5</td>
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*p<0.05, vs standard LMA, flexible LMA

position and the tilted position (ΔOLP) with the sLMA was positive in 11 patients, remained unchanged in 4 patients, and was negative in 5 patients. The average ΔOLP for the sLMA was +2.2 cm H₂O, which was the largest among the three types of LMA. The ΔOLP for the fLMA was positive in 8 patients, remained unchanged in 2 patients, and was negative in 10 patients; the average ΔOLP was +0.3 cm H₂O. For the fLMA, the ΔOLP was positive in 5 patients, remained unchanged in 5 patients, and was negative in 10 patients; the average ΔOLP was −0.4 cm H₂O. The change in oropharyngeal leak pressure with body position was smaller for the fLMA than for the sLMA or fLMA, but this difference was not significant.

Correlation between fiberoptic score and oropharyngeal leak pressure (Table 3)
There was no significant correlation between fiberoptic score and oropharyngeal leak pressure for the three types of LMA, except for the fLMA in the frontal position.
Fig. 2. Change in oropharyngeal leak pressure between the 2 body positions for each patient. Twenty lines indicate the Δ oropharyngeal leak pressure (cm H₂O). The range of difference in Δ oropharyngeal leak pressure was smallest for intubating LMA (iLMA).

TR : Tilting right  FU : Facing up

Table 3. Correlation between score and oropharyngeal leak pressure

<table>
<thead>
<tr>
<th>LMA Type</th>
<th>Position</th>
<th>Equation</th>
<th>R²</th>
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<tr>
<td>standard LMA</td>
<td>facing up</td>
<td>Y = -0.013X + 2.291</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>tilting right</td>
<td>Y = 0.04X + 1.476</td>
<td>0.052</td>
</tr>
<tr>
<td>flexible LMA</td>
<td>facing up</td>
<td>Y = 0.118X - 0.072</td>
<td>0.358*</td>
</tr>
<tr>
<td></td>
<td>tilting right</td>
<td>Y = 0.034X + 1.331</td>
<td>0.026</td>
</tr>
<tr>
<td>intubating LMA</td>
<td>facing up</td>
<td>Y = -0.61X + 4.006</td>
<td>0.066</td>
</tr>
<tr>
<td></td>
<td>tilting right</td>
<td>Y = -0.036X + 3.65</td>
<td>0.024</td>
</tr>
</tbody>
</table>

*p < 0.05

Discussion

External forces, such as changes in patient's position and unexpected movements during anesthesia, are thought to directly affect the position of the LMA tube and subsequently impact on the function of the mask by altering the fit of the mask against the surrounding tissue. We examined three types of LMA with differing tubing characteristics by measuring sealing pressure and observing the position of the fiberoptic bronchoscope.

For the fLMA, the lowest score of 1 was recorded for 50% of patients in the frontal position and 40% of patients in the tilted position. In contrast, for the iLMA the highest score of 4 was recorded for approximately 50% of patients in both body positions. These results suggest that proper positioning is more difficult for the fLMA than for the iLMA,
despite the use of the same insertion method. It appears that the physical characteristics of the tube affect the ease of insertion. Since hard tubes are inserted along the curvature of the hard palate, the tendency is that the greater the curvature, the easier the insertion. When the iLMA was first introduced, it was assumed that insertion would be difficult due to the inflexible metal component of the iLMA tubing. Instead, clinical experience demonstrates that the iLMA is easier to insert than the sLMA. The results of the present study also show that the iLMA is easier to insert than the sLMA. We examined three types of LMA inserted by a skilled anesthesiologist with 10 years experience in the application of LMAs for anesthetic management. Brimacombe reports that the success rate of LMA insertion at the first attempt increases and the incidence of complications decreases with the number of cases performed by the anesthesiologist. The results of the present study may have been different for an anesthesiologist not familiar with LMA insertion.

In both body positions, the iLMA provided a higher oropharyngeal leak pressure than the sLMA or the fLMA. Brain suggests that part of the reason for this may be the soft tubes of the sLMA or fLMA allowing the mask to slide laterally onto one or the other side of the cervical bodies. By comparison, the rigid construction of the iLMA tube forces the mask to remain in the median position and exert a greater force on the larynx by pushing further forward. The present study shows that of the three types of LMA the iLMA provides the highest airway sealing pressure. Brimacombe also reports higher oropharyngeal leak pressure for the iLMA than for the sLMA or fLMA.

In the past, it was generally thought that the lower the intracuff pressure, the lower the LMA oropharyngeal leak pressure. Hence, when air tightness was insufficient, physicians would further inflate the cuff. According to Keller et al., when the intracuff pressure is increased above a certain level, tissues coming into contact with the mask become damaged thereby changing the anatomical characteristics of the larynx, which in turn leads to reduced oropharyngeal leak pressure and poor positioning of the LMA. To avoid these problems, the intracuff pressure was maintained at the currently accepted intracuff pressure of 60 cm H_2O for all patients in the present study.

Since the oropharyngeal leak pressure and fiberoptic scores were higher for the iLMA than for the sLMA and fLMA, it is reasonable to assume that the higher the fiberoptic score (the better the LMA positioning), the greater the oropharyngeal leak pressure. Nevertheless, correlations between oropharyngeal leak pressure and fiberoptic scores were studied with respect to three types of LMA in each body position. For the three types of LMA, there was no significant correlation between fiberoptic position and oropharyngeal leak pressure, except for the fLMA in the face up position. The above findings suggest that a factor or factors, other than LMA positioning and mask, has an effect on oropharyngeal leak pressure. Berry et al. and Joshi et al. revealed a positive correlation, while Brimacombe reported a negative correlation, between oropharyngeal leak pressure and fiberoptic position. This inconsistency suggests that the anatomical factors influencing the efficacy of sealing of the respiratory tract by LMAs are unclear.

Although the LMA consists of two components, namely a mask and a tube, the focus of the majority of LMA research has been on masks. Many studies have investigated improvements in LMA material or shape of the mask, appropriate mask size, cuff volume, and injury caused by contact with the mask. Likewise, numerous studies have examined airway sealing pressure in relation to LMA positioning, LMA size, and cuff volume. By
A Comparison of Three Types of LMA

comparison, there have been no studies investigating the physical characteristics of the LMA tubes in relation to these issues. For safe use of an LMA it is essential to maximize airway sealing pressure. The present study shows that the iLMA, consisting of a silicon-covered metal tube, provides the highest oropharyngeal leak pressure. This suggests that an optimal level of sealing pressure will be obtained using an LMA tube made of a rigid material. The disadvantage of this approach is that sustained use of the iLMA is known to be invasive to the surrounding tissues and cause damage. We recommend that LMA tubes only be made of rigid material when used as a conduit for tracheal intubation.

This study investigated three types of LMA in which materials and shapes of the mask are almost identical, except for differences in the physical characteristics of the tubes. We found that the differences in oropharyngeal leak pressure and fiberoptic score between the three types of LMA are related to tube characteristics. This study provides evidence that the LMA tube is an important factor in determining the airtightness of the LMA against surrounding tissue.

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