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ORIGINAL ARTICLE

Randomized evaluation of the size 2 laryngeal tube and classical laryngeal mask airway in different head and neck positions in children under positive pressure ventilation

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Abstract

Purpose The aim of this study was to evaluate the applicability of the laryngeal tube (LT) size 2 and the classical laryngeal mask airway (LMA) size 2 in different head–neck positions under positive pressure ventilation in children by measuring leak pressures, peak pressures and the achievable tidal volumes under positive pressure ventilation.

Methods Forty children were randomized to receive airway management by either the LT or LMA as the primary device. Leak pressures, peak pressures and tidal volumes under positive pressure ventilation were measured in the neutral, anteflection, retroversion, left-rotation and right-rotation head–neck positions.

Results In all head–neck positions, the leak pressures were significantly higher for the LT than for the LMA (neutral 25.9 ± 7.0 vs. 19.1 ± 5.7 cmH_2O; anteflection 29.7 ± 7.1 vs. 24.2 ± 8.9 cmH_2O; retroversion 24.1 ± 7.6 vs. 17.2 ± 6.9 cmH_2O). In both devices, the peak ventilation pressures were higher in the anteflection position (LT 27.1 ± 6.3 cmH_2O; LMA 17.8 ± 6.7 cmH_2O) than in the retroversion position (LT 13.7 ± 3.9 cmH_2O; LMA 12.7 ± 3.6 cmH_2O). Compared to the respirator settings, lower tidal volumes were achieved in the anteflection position (LT 65 ± 48 vs. 129 ± 38 ml, LMA 100 ± 21 vs. 125 ± 29 ml) as compared to the other positions.

Conclusion Based on our results, we suggest that in anaesthetized children, the size 2 LT, compared to the size 2 LMA, may be more suitable for positive pressure ventilation due to favorable leak and peak pressures. Both devices can be safely used in head–neck positions other than neutral. Most disadvantageous with regards to the measured parameters was the anteflection position, especially for the LT.

Keywords Supraglottic · Pediatric anesthesia · Leak pressure · Peak pressure · Different head–neck positions

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Introduction

Since its invention in 1983 [1], the laryngeal mask airway (LMA) has gained worldwide acceptance as a routinely used airway management device. At the present time, the laryngeal mask is used even in surgical procedures such as adenotonsillectomy or myringotomy which require head and neck positions other than neutral and for which traditionally the endotracheal tube had been used [2–4]. However, recently published studies in adults have found that the head and neck position has a significant impact on the effectiveness of ventilation [5, 6]. Another supraglottic airway device, the laryngeal tube (LT; VBM Medizintechnik, Sulz, Germany), a single-lumen tube that is closed at the distal end with an esophageal balloon and equipped a pharyngeal cuff to secure the airway, is becoming increasingly popular. Whether this device is applicable in different head and neck positions in children has not been systematically investigated to date.

The aim of the prospective, randomized, controlled trial reported here was to assess the applicability of the laryngeal tube "LT" size 2 (VBM Medizintechnik) compared to the laryngeal mask "cLMA" size 2 (Laryngeal Mask Co., Henley-on-Thames, UK) in different head and neck positions in children by measuring oropharyngeal leak pressures, peak pressures and the tidal volumes under positive pressure ventilation.

Materials and methods

With ethics committee approval and after obtaining written informed consent from the parents or guardians, 40 children aged ≥1 year who were scheduled for minor urological surgery were enrolled in our study. Exclusion criteria were body weight of >20 kg, American Society of Anesthesiologists physical status III and higher, upper airway morbidity or any risk of regurgitation of gastric content. Airway management was provided either with a multiple use classic LMA or a multiple use laryngeal tube LT, with randomization of the children to either device through the toss of a coin.

The children were premedicated with midazolam 0.5 mg/kg orally 30 min before the induction of anesthesia. In the operating room, monitoring included electrocardiogram, non-invasive blood pressure, pulse oximetry, end-tidal CO_2, expired sevoflurane concentration and a precordial stethoscope. Anesthesia was induced by inhaled sevoflurane 8 vol % in oxygen via a facemask. Following induction, each child received an intravenous cannula, and fentanyl 2 μg/kg was given according to our standard anesthesia protocol. Hereafter, when the conditions were suitable (jaw relaxation, absence of movement), the respective device was inserted according to the manufacturers' recommendations. Anesthesia was maintained with sevoflurane in oxygen/air (fraction of inspired O_2 0.5) and remifentanil (0.25 μg/kg/min). No neuromuscular blocking agent was given.

After inflation of the cuff with the recommended volume, the device was connected to the breathing system, and the child was manually ventilated. Adequacy of ventilation was assessed by observing chest movements and end-tidal CO_2 tension waveforms. If it was not possible to ventilate the lungs, the airway device was removed, and another attempt to position the device was performed. A maximum of three attempts was allowed. If placement had failed after three attempts, an endotracheal tube was used. After successful positioning, the device was fixed with tape, and the cuff pressure was measured and adjusted to a maximal pressure of 60 cmH_2O. All subsequent measurements were performed with the adjusted cuff pressure.

Measurements

All measurements were performed at a depth of anesthesia allowing surgical manipulation without movement of the patient or significant vegetative reactions. Each child was placed in each of the following head positions: the neutral position (horizontally without elevation on the operating room table), anteflected to the chest (about 45°), retroflected to the neck (about 45°), rotated to the right side (about 70°) and rotated to the left side (about 70°). Measurements were recorded 30–60 s after adjustment of the head position. Between the different head positions, the patient's head was placed back in the neutral position for at least 1 min.

Leak pressures were determined by closing the expiratory valve of the breathing system at a fresh gas flow of 3 l/min. We recorded the airway pressure at which the dial on the manometer reached equilibrium [7]. When measuring the leak pressure, any air entering the stomach was noted by auscultation of the epigastrium with a stethoscope.

When measurements of the leak pressures were completed, the child was once again re-positioned in the neutral position, and the respirator was switched to positive pressure ventilation with a tidal volume of 8 ml/kg and a respiration frequency of 20–30/min (depending on the child's age). After 5 min of mechanical ventilation in the neutral position, the peak ventilation pressures and the tidal volumes, as measured by the respirator and indicated on the display, were recorded. Again, each child was placed in each of the five head positions and the position maintained for at least 30–60 s, as described above, before values were recorded.

Statistical analysis

The primary objective was to compare leak pressures in different head positions. In an a priori power analysis, 11 patients per group were calculated to be sufficient to determine a 30 % difference in leak pressures at a power of 0.8, $\alpha = 0.05$ (Sampsize ver. 0.6; Source Forge.net, Geeknet Media, Dice Holdings, New York, NY).

Statistical analysis was performed with SigmaStat ver. 3.0 (SPSS Science Software, Erkrath, Germany). Unless otherwise stated, data are expressed as mean values ± standard deviation. Distribution of data was determined using Kolmogorov–Smirnov analysis. Data of the two groups were compared and analyzed using the Student *t* test and Mann–Whitney *U* test as appropriate. For the analysis of nominal data, we used the chi-square analysis or Fisher's exact test. $p < 0.05$ was considered statistically significant.

Results

According to the randomization, 18 children were assigned to the LT and 22 to the LMA. Patient characteristics and surgical data were comparable between groups (Table 1).

The LT was successfully placed at the first attempt in 14 children (78 %), at the second attempt in one child (6 %) and at the third attempt in two children (10 %). One child (6 %) was endotracheally intubated after three failed attempts. All LMAs could be successfully inserted at the first (21 children, 95 %) or second attempt [1 child, 5 %; not significant (n.s.)].

Intracuff pressures

The initial cuff pressures after inflating the cuffs with the volumes recommended by the manufacturers were significantly lower in the LT group than in the LMA group (77.8 ± 17.2 vs. 101.3 ± 20.7 cmH_2O, respectively; $p < 0.05$).

Table 1 Patient characteristics

Patients' characteristics	LT ($n = 18$)	LMA ($n = 22$)	p value[a]
Age (years)	3.8 ± 2.1	3.5 ± 2.1	n.s.
Height (cm)	101.0 ± 18.1	101.1 ± 13.6	n.s.
Weight (kg)	15.9 ± 4.0	15.4 ± 2.9	n.s.
Circumcision	8	8	n.s.
Orchidopexy	5	7	n.s.
Other surgery	5	7	n.s.
Mallampati score I/II	16/2	21/1	n.s.

Data are given as mean ± standard deviation (SD) or number of patients (n), where appropriate

LT Laryngeal tube, *LMA* laryngeal mask airway, *n.s.* not significant (i.e. $p \geq 0.05$)

[a] p value is LT vs. LMA

Table 2 Mean oropharyngeal leak pressures

Head–neck position	LT	LMA	p value[a]
Neutral position	25.9 ± 7.0	19.1 ± 5.7	<0.05
Anteflection	29.7 ± 7.1	24.2 ± 8.9	<0.05
Retroversion	24.1 ± 7.6	17.2 ± 6.9	<0.05
Right rotation	26.9 ± 5.4	20.8 ± 6.1	<0.05
Left rotation	27.1 ± 6.6	21.0 ± 6.1	<0.05

Data are given as mean ± SD (cmH_2O)

[a] p value is LT vs. LMA

Oropharyngeal leak pressures

With the LT, the mean oropharyngeal leak pressures were significantly higher in anteflection (29.7 ± 7.1 cmH_2O; $p < 0.05$), but similar in retroversion (24.1 ± 7.6 cmH_2O; n.s.) and in left/right rotation (27.1 ± 6.6/26.9 ± 5.4 cmH_2O; n.s.) compared to the neutral position (25.9 ± 7.0 cmH_2O). With the LMA, the mean oropharyngeal leak pressures were significantly higher in anteflection (24.2 ± 8.9 cmH_2O; $p < 0.05$), but similar in retroversion (17.2 ± 6.9 cmH_2O; $p < 0.05$) and in left/right rotation (21.0 ± 6.1/20.8 ± 6.1 cmH_2O; n.s.) compared with the neutral position (19.1 ± 5.7 cmH_2O). In all head and neck positions mean oropharyngeal leak pressures were significantly lower with the LMA than with the LT (Table 2; $p < 0.05$).

Oropharyngeal peak pressures

In both devices, the peak pressures as displayed by the respirator were higher with the head anteflected compared to all other positions (LT 27.1 ± 6.3 cmH_2O; LMA 17.8 ± 6.7 cmH_2O; $p < 0.05$). Comparing both devices, the peak pressures were significantly higher with the laryngeal tube than with the laryngeal mask in the neutral position (20.5 ± 7.0 vs. 14.2 ± 4.7 cmH_2O; $p < 0.05$) and in the anteflected position (27.1 ± 6.3 vs. 17.8 ± 6.7 cmH_2O; $p < 0.05$). There were no differences between the devices with the head retroverted and left and right rotated (Table 3).

Tidal volumes

For both devices, there were no significant differences between the set and the measured tidal volumes in the neutral, retroverted and left- and right-rotated head positions. In the anteflected head position, both devices showed significantly reduced tidal volumes compared to the respirator settings (LT 65 ± 48 vs. 129 ± 38 ml; LMA 100 ± 21 vs. 125 ± 29 ml), with the LT being more affected than the LMA (Table 4).

Table 3 Mean peak pressures

Head–neck position	LT	LMA	p value[a]
Neutral position	20.5 ± 7.0	14.2 ± 4.7	<0.05
Anteflection	27.1 ± 6.3	17.8 ± 6.7	<0.05
Retroversion	13.7 ± 3.9	12.7 ± 3.6	n.s.
Right rotation	16.3 ± 6.4	14.4 ± 5.0	n.s.
Left rotation	15.9 ± 6.1	14.1 ± 4.7	n.s.

Data are given as the mean ± SD (cmH_2O)

[a] p value is LT vs. LMA

Table 4 Tidal volumes

Respirator setting and head–neck position	LT	LMA	*p* value[a]
Respirator setting	129 ± 38	125 ± 29	
Neutral position	119 ± 48	118 ± 27	n.s.
Anteflection	65 ± 48	100 ± 21	<0.05
Retroversion	126 ± 38	116 ± 25	n.s.
Right rotation	125 ± 40	121 ± 21	n.s.
Left rotation	117 ± 47	124 ± 22	n.s.

Data are given as the mean ± SD (ml)

[a] *p* value is tidal volume measured compared to the respirator setting

Discussion

In our study we investigated the applicability of the size 2 classical LMA and the LT in different head positions in children by measuring leak pressure, peak pressure and the achievable tidal volume under positive pressure ventilation. Both devices allowed effective ventilation with limitations in the anteflected head position, especially for the LT.

Leak pressures

High leak pressure is assumed to be a sign of a better airway seal and protection against gastric inflation as well as reflux [8, 9]. Compared to adult devices, pediatric size LMAs have been found to have lower leak pressures and, therefore, are considered to be inferior due to an incomplete fit of the pediatric oropharyngeal space [7]. In our investigation, the leak pressures in the neutral head position were significantly higher with the LT than with the LMA, which is in accordance with the results of previous studies in adults [5, 9] and, more recently, also those in a pediatric patient population [8, 10]. When the head position was changed with the LMA inserted, extension of the head towards the neck decreased the mean oropharyngeal leak pressure compared to the neutral position, whereas anteflection of the head towards the chest led to increased leak pressures. Keller et al. [11] suggested that anteflection of the neck causes a reduction in the antero-posterior diameter of the larynx, whereas retroversion causes a respective increase, leading to changes in the conformity of the cuff of the LMA with the pharynx. In contrast, in our investigation the leak pressures with the LT remained unaffected by these suggested morphological effects of the different head positions. Moreover, all leak pressures with the LT were significantly higher than those with the LMA, as also reported previously [8].

Positive pressure ventilation

Positive pressure ventilation with the LMA has always been controversial because of the low pressure seal and the potential gas leakage into the stomach with subsequent risk of gastric distension and regurgitation [12]. In our investigation, we were always able to achieve sufficient positive pressure ventilation when using the LMA in the neutral head position; we also achieved the same results with the LT. Cook et al. [13] and Genzwuerker et al. [8] recommended the LT as the preferable device for positive pressure ventilation because of its higher leak pressures. However, Inagawa et al. [14] argued that a higher airway seal cannot be taken as a sign of adequate positioning. Ocker and colleagues [9] suspected that in the case of inadequate positioning of the esophageal balloon, air can readily enter the esophagus. In our investigation, sufficient ventilation was achieved with both devices also after positioning the head left rotated, right rotated and retroverted to the neck. The achievable tidal volumes and the peak pressures in these positions were comparable to those in the neutral position. However, the achievable tidal volume was significantly reduced and the peak pressures were significantly higher with the LMA, and even more with the LT, when positioning the head anteflected to the chest, despite the highest leak pressures in this position. It is evident that although a higher leak pressure might imply a better airway seal [8] and anteflecting the head and neck may improve the seal, at least with the LMA [11], ventilation may not necessarily be improved. In our investigation, the highest leak pressures were achieved with the LT and the patient in the anteflected position. However, in this position, the peak pressures were also the highest and the achievable tidal volumes were the lowest compared to all other positions. Therefore, in the case of insufficient positive pressure ventilation with the LT or LMA, the head of a child should be rotated or retroverted instead of anteflected. These limitations of a supraglottic airway device in the anteflected position have also been demonstrated with the newer devices, i-gel and LT-S II [15, 16]. The results of our comparison of the peak and leak pressures—and their differences—of both devices suggest that the LT is preferable over the LMA for positive pressure ventilation in all head and neck positions except the anteflected position.

Cuff filling volume

Both manufacturers provide a recommended maximum filling volume for the cuffs of their devices. In our investigation, we initially inflated the cuffs exactly with the recommended volumes. When measuring the cuff pressures thereafter, we found that in nearly every child the cuff pressures of both devices exceeded 60 cmH_2O, the pressure that is considered safe to allow sufficient oropharyngeal tissue blood circulation [17]. Recent investigations have shown, at least for the LMA, that deflating the cuff to lower pressure values might be even more recommendable because of reduced pharyngolaryngeal complications [18, 19]. Our data confirm results from previous investigations recommending the routine use of a cuff pressure gauge and adjustment of the cuff pressure in both devices, even when the filling of the cuff is performed with the volume recommended by the manufacturer [20, 21].

Limitations

There are some limitations to our investigation. The investigated head positions were maintained only for several minutes as it was considered potentially harmful to maintain these positions for a longer time. Therefore, from our data no conclusions can be drawn for longer periods of time. Additionally, we cannot exclude that the studied head positions could have led to a partial kinking of the LMA over time. However, in a previous study, Keller and Brimacombe showed that there are no differences in the leak pressures due to the different head positions between a standard laryngeal mask and the flexible, non-kinking laryngeal mask [11]. We therefore limited our analysis to size 2 devices. Because it is well known that especially smaller sizes of devices show higher rates of complications in terms of displacement and leak, conclusions concerning other sizes have to be make with caution.

Finally, we investigated two first-generation devices. Although the classic devices are still in widespread clinical use, second-generation LMA and LT are now available—with advantages [22–24], but also with comparable limitations [5, 16].

Conclusion

The results of our investigation demonstrate that the size 2 LT and LMA are both suitable for use in a pediatric patient population when the head is rotated left or right or is retroflected. However, both devices have limitations with an anteflected head, with the LMA being less affected. The greater differences between leak pressures and peak pressures with the LT can be interpreted as an advantage for this device when positive pressure ventilation is used.

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