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Identification of laryngeal mask airway failure in pediatric patients: a pilot study

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ABSTRACT

Aims: The study was conducted to identify predictors of laryngeal mask airway (LMA) placement failure in pediatric patients and to investigate the relationship between LMA placement failure and postoperative airway complications.

Methods: This study was designed as a prospective observational trial including 66 ASA I patients aged 2-12 years who were scheduled for elective surgery. The patients were divided into two groups based on the placement of the LMA: group S (successful placement of LMA at first attempt) and group non-S (non-successful placement of LMA at first attempt). The relationship between LMA placement failure with airway leakage, peak airway pressure, peripheral oxygen saturation, and expiratory CO_2 measurements was evaluated.

Results: Airway leakage and peak airway pressure was significantly higher in group non-S when compared to group S [(median-IQR) (ml); 10 (4) vs. 5 (5); p<0.001] and [(median-IQR) (cm-H_2O); 14 (3.5) vs.13 (2); p=0.038], respectively. Patients in group non-S exhibited a higher incidence of postoperative respiratory complications when compared to group S (72.4% vs 27.6%; p<0.001).

Conclusion: Airway leak and peak airway pressure can serve as determinants of LMA failure in pediatric patients.

Keywords: Laryngeal mask airway, pediatric surgery, airway management, anesthesia

INTRODUCTION

Laryngeal mask airway (LMA) is a supraglottic airway device that is inserted into the pharynx for the purpose of ventilation. One significant benefit of LMA is that it is simpler to insert than an endotracheal tube during general anesthesia.[1] It has gained popularity as it can be inserted more rapidly when compared to endotracheal intubation, particularly by healthcare personnel with limited experience.[2] Furthermore, the utilization of a laryngeal mask has a lower incidence of complications, including postoperative cough, laryngospasm, soft tissue trauma, and sore throat, in comparison to tracheal intubation, as well as fewer hemodynamic changes.[1]

In comparison to endotracheal intubation, LMA applications present a variety of hazards, including a higher risk of gastric insufflation, a lower level of airway protection, and a higher incidence of hypoxemia.[3] Various studies have focused on lowering these risks.[2,4] Identification of risk factors for LMA failure could help anesthesiologist with evaluation of airway conditions and improvement of patient management.[5,6] Nevertheless, although objective data such as air leak, high airway pressure, inadequate lung ventilation, and single lung ventilation can be used to detect inappropriate or failed endotracheal intubation, no objective criteria is available for the detection of LMA misplacement.[7-9]

The aim of this study was to determine objective predictors for LMA placement failure in pediatric patients following anesthesia induction and to examine the correlation between LMA placement failure and postoperative airway complications.

METHODS

Ethics

This single-center, prospective, observational study was approved by Samsun University Clinical Researches Ethics Committee (Date: 23.08.2023, Decision No: 2023/15/13) and registered with clinicaltrials.gov (NCT06337006). The study was conducted between 15/09/2023 and 15/07/2024 in a tertiary women's health and pediatric hospital. Written informed consent was obtained from all parents of patients before enrollment. The study was conducted in accordance with the ethical guidelines of the Declaration of Helsinki.

Study Populations

The study included patients between the ages of 2 and 12 who were scheduled for elective out-patient surgery (hernia repair, circumcision, orthopedic corrections etc.), who had an American Society of Anesthesiologists (ASA) physical

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status score of 1, and where an anesthesiologist planned to use a LMA for upper airway support during surgery. The study excluded patients who were at risk of gastroesophageal reflux and gastric aspiration, had a known airway malformation, hyperthyroidism, goiter, or known airway mass, had a surgery >1 hour, or were considered to have a difficult airway prior to anesthesia.

Anesthesia with LMA Insertion

A pre-anesthesia check was performed before surgery and all children fasted in accordance with protocol.[10] Upon arrival in the operating room, the patient was connected to a multichannel monitor that displayed heart rate, peripheral oxygen saturation (SpO_2), and noninvasive blood pressure (systolic, diastolic, and mean arterial pressure). Before the induction of anesthesia, vital parameters were recorded. The institute's protocol was followed when administering standard anesthesia to all children.

In the operating room prior to induction, children were preoxygenated with 100% oxygen at 6 L/min for 3 minutes with a face mask and the head held in a neutral position. Anesthesia induction was administered to children with intravenous (IV) access using propofol 2-3 mg/kg and fentanyl 1 µg/kg. Children lacking IV access underwent induction with inhaled sevoflurane. The value of basal End tidal CO_2 ($EtCO_2$) (mmHg) was recorded during mask ventilation. Adequate depth of anesthesia was determined to be achieved when the jaw was fully relaxed and the eyelash reflex was dissipated. Rocuronium 0.2 mg/kg IV was administered for muscle relaxation after the mask ventilation was confirmed to be adequate.

The capsule of the classic LMA (Intavent Direct, Maidenhead, UK) was evenly coated with 1-2 ml of lidocaine gel. The manufacturer's recommendation was followed in selecting the appropriate size of the LMA (2 for 10-20 kg and 1.5 for 5-10 kg). An experienced anesthesiologist positioned the fully deflated LMA with the patient's head in a neutral position. The patient's mouth was then opened, and the device was advanced along the hard palate while the patient was held parallel to the torso. The manufacturer's instructions were followed to ensure that the cuff of the device was adequately inflated. The following criteria were used to determine successful LMA placement: equal chest movement on inspiration, square wave capnograph, no gastric insufflation or air leak by sound and adequate tidal volume. If all criteria were met, LMA placement was accepted as a success (group S), and if one or more criteria failed, patients were deemed to have unsuccessful LMA placement (group non-S). The mechanical ventilator is equipped with an adjustable pressure limiting (APL) valve that operates at 25 cm-H_20, a tidal volume (VT) of 8 ml/kg, and a fresh gas flow (FGF) of 3 L/min. The inspiration-expiration ratio was 1/2. The arithmetic average of the VT, expiratory VT, airway peak pressure, SpO_2, and $EtCO_2$ measurements was recorded by an additional experienced anesthesiologist in three respiratory cycles following the initial placement of the LMA. Airway loss (ΔVT) was determined by subtracting the adjusted VT from the expiratory VT. SpO_2 and $EtCO_2$ measurements, airway leak volume, and airway peak pressure were identified as potential predictors of LMA placement failure. Postoperative airway complications were identified and documented as cough attack, bleeding, sore throat, soft tissue trauma, and laryngospasm-bronchospasm.

Outcomes

The primary outcome was the identification of the determinants for LMA placement failure, while the secondary outcome was the determination of the relationship between LMA placement failure and postoperative airway complications.

Statistical Analysis

Using a 95% confidence level (1-α), a test power of 95% (1-β), and an effect size of d=1.016, the sample size, calculated using G*power, was determined to be a minimum of 22 cases for each group and a total of at least 44 cases.[11] To account for potential data loss, the authors intended to conduct the trial with a minimum of 25 patients in each group. Statistical analyses were conducted using SPSS version 26 (IBM Corporation, Armonk, NY, USA.) Data normality was tested using the Kolmogorov-Smirnov test and the Shapiro-Wilk test for groups with sample sizes below 30. Quantitative data were presented as mean [±standard deviation (SD)] or median [interquartile range (IQR)] and frequency (percentage) for categorical data. Quantitative variables were compared using the student T test or Mann-Whitney U test. Categorical data were compared using the Chi-square ($\chi 2$) or Fisher's exact test. In LMA placement failure, ROC analysis was used to calculate the sensitivity and specificity for the difference between adjusted tidal volume and measured inspiratory tidal volume, airway peak pressure, peripheral oxygen saturation, and expiratory CO_2. $p<0.05$ was used as statistical significance in all tests.

RESULTS

The study was completed with 66 patients. The flow chart of the study is shown in **Figure 1**. LMA placement failure was seen in 35.6% of patients. Patients' demographic and clinical data are shown in **Table**. Body weight (kg) [(median-IQR); 15 (9.7) vs. 22 (13); p=0.007] and body-mass index (BMI, kg/m^2) [(median-IQR); 14.2 (3.9) vs. 16.8 (4.3); p=0.013] were found to be lower in group non-S when compared to group S. ΔVT measured to assess airway leak [(median-IQR) (ml); 10 (4) vs. 5 (5); p<0.001] and airway peak pressure [(median-IQR) (cm-H_2O); 14 (3.5) vs.13 (2); p=0.038] was found to be significantly higher in group non-S. SpO_2 was similar between groups before anesthesia induction and after LMA placement ($p>0.05$). $EtCO_2$ was similar between two groups before induction. However, $EtCO_2$ was higher in group non-S when compared to group S after LMA placement [(median-IQR); 39 (3) vs. 37 (2); p=0.001]. However, $EtCO_2$ was within normal physiological rates in both groups after LMA placement. The variables that predict the failure of LMA placement by group are illustrated in **Figure 2**.

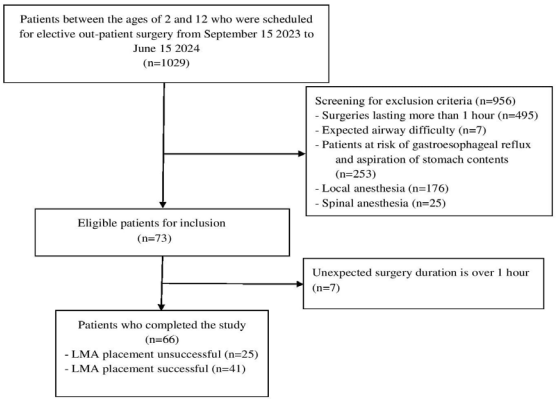

Figure 1. Flowchart of the study

Table. Patient demographic and clinical characteristics

	All patients	Group S (n=41)	Group non-S (n=25)	p
Demographics				
Age (year) (median-IQR)	4 (4)	4.5 (4.75)	2.5 (3.25)	0.064
Gender (male) (n, %)	60 (90.9)	36 (60)	24 (40)	0.261
Body weight (kg) (median-IQR)	18 (11)	22 (13)	15 (9.7)	0.007
Body-mass index (kg/m^2) (median-IQR)	15.9 (4.6)	16.8 (4.3)	14.2 (3.9)	0.013
Surgical procedure				0.012
Abdominal surgery (n, %)	23 (34.8)	19 (82.6)	4 (17.4)	
Genitourinary surgery (n, %)	43 (65.2)	22 (51.2)	21 (48.8)	
Before anesthesia induction				
Heart rate (minute/beat) (median-IQR)	120 (24.2)	118 (26)	131 (21.5)	0.003
SpO_2 (%) (median-IQR)	100 (1)	100 (1)	100 (1)	0.540
$EtCO_2$ (mmHg) (median-IQR)	36 (2)	36 (2)	36 (2.5)	0.661
Systolic artery pressure (mmHg) (mean±SD)	105.9±11.9	107.8±10.6	102.8±13.4	0.099
Diastolic artery pressure (mmHg) (mean±SD)	57.6±18.2	55.4±14.5	61.2±12.7	0.060
Mean artery pressure (mmHg) (mean±SD)	73.7±10.5	72.8±10.6	75.1±12.1	0.410
After LMA attempt				
Heart rate (min/beat) (median-IQR)	111 (33.7)	104 (16)	123 (25)	0.001
SpO_2 (%) (median-IQR)	100 (1)	100 (1)	100 (0)	0.435
$EtCO_2$ (mmHg) (median-IQR)	38 (3)	37 (2)	39 (3)	0.001
Systolic artery pressure (mmHg) (mean±SD)	96.1±9.4	96.7±9	96±10.3	0.978
Diastolic artery pressure (mmHg) (mean±SD)	49.8±8.8	48.3±9.5	52.1±9	0.098
Mean artery pressure (mmHg) (mean±SD)	65.2±9.5	64.3±7.9	66.7±8.8	0.245
Mechanical ventilation				
Adjusted VT (ml) (median-IQR)	150 (82.5)	170 (100)	120 (70)	0.026
Expiratory VT (ml) (median-IQR)	140 (100)	170 (100)	90 (67.5)	<0.001
ΔVT (ml) (median-IQR)	8 (20)	5 (5)	10 (4)	<0.001
Peak airway pressure (cm-H_2O) (median-IQR)	13 (3)	13 (2)	14 (3.5)	0.038
Postoperative complication				
Cough (n, %)	7 (10.6)	2 (28.6)	5 (71.4)	0.221
Minimal bleeding (n, %)	6 (9.1)	1 (16.7)	5 (83.3)	0.082
Sore throat (n, %)	4 (6.1)	3 (75)	1 (25)	0.297
Tissue trauma (n, %)	3 (4.5)	1 (33.3)	2 (66.6)	0.552
Cough and minimal bleeding (n, %)	9 (13.6)	1 (11.1)	8 (89.1)	0.010

IQR: Interquartile range, SpO_2: Peripheral oxygen saturation, $EtCO_2$: End-tidal CO_2, CO_2: Carbon dioxide, SD: Standard deviation, LMA: Laryngeal mask airway, VT: Volume tidal, ΔVT: Adjusted VT-expiratory VT

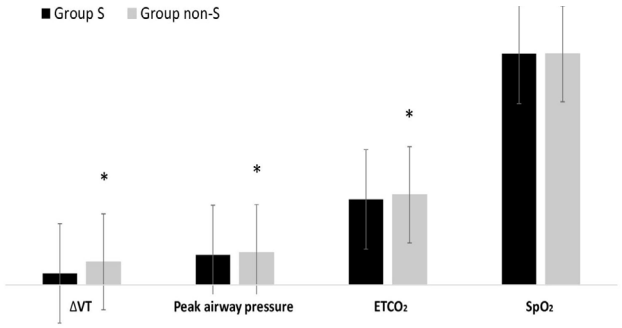

Figure 2. The variables that predict the failure of LMA placement by groups. $EtCO_2$, End-tidal CO_2; SpO_2, Peripheral oxygen saturation; ΔVT, adjusted VT-expiratory VT

LMA: Laryngeal mask airway, $EtCO_2$: End-tidal CO_2, CO_2: Carbon dioxide, SpO_2: Peripheral oxygen saturation, ΔVT: Adjusted VT-expiratory VT, VT: Volume tidal

Following the establishment of the ROC curve for ΔVT and peak airway pressure (**Figure 3**), the cutoff values for predicting the failure of LMA placement were determined to be 7 ml and 13.5 cm-H_2O, respectively. The sensitivities and specificities for ΔVT were 80% and 65% (AUC, 0.790; 95% CI, 0.682-0.898; p<0.001) and for airway peak pressure were 60% and 61% (AUC, 0.651; 95% CI, 516-787; p=0.040), respectively.

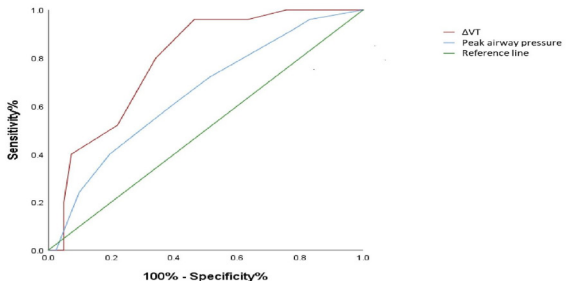

Figure 3. Receiver operating curve for changes in ΔVT and peak airway pressure on the risk of developing failure of LMA placement. It is a plot of the true positive rate (sensitivity) versus the false positive rate (1-specificity) at various thresholds of ΔVT and peak airway pressure. The area under the curve is a measure of the diagnostic accuracy for changes in ΔVT and peak airway pressure of predicting failure of LMA placement

ΔVT: Adjusted VT-expiratory VT, VT: Volume tidal, LMA: Laryngeal mask airway

The prevalence of all defined postoperative respiratory complications, except for sore throat (group non-S vs group S; 25 vs 75%; p=0.297), was higher in group non-S when compared to group S (72.4% vs 27.6%; p<0.001).

DISCUSSION

As SpO_2 did not significantly change between before anesthesia induction and after LMA placement, and as $EtCO_2$ remained within normal physiological ranges despite a statistically significant increase between before anesthesia induction and after LMA placement, we conclude that SpO_2 and $EtCO_2$ cannot be determining factors of LMA placement failure in children. We observed that ΔVT and peak airway pressure were significantly higher in group non-S when compared to group S. Therefore, ΔVT and peak airway pressure could be used as determining factors of LMA placement failure.

In order to prevent potential hypoxia and hypercarbia, it is essential to provide optimal respiratory support during general anesthesia.[12,13] LMA safeguards patients from hypoxia during surgical procedures that are conducted under general anesthesia or sedation. Khatavkar et al.[14] demonstrated that LMA facilitated stable O_2 saturation in children during fiberoptic bronchoscopy under sedation, in contrast to nasal airway-assisted bronchoscopy. In addition, it has been reported that the LMA is more effective in preventing hypoxia in pediatric patients compared to tracheal intubation.[1,15] It is generally emphasized that the successful prevention of hypoxia is achieved through the proper application of LMA. Nevertheless, the criteria for effectively applying LMA are not clearly defined. In their study examining the efficacy of LMA placement in children, Asida et al.[16] defined SpO_2 ≤92% as unsuccessful LMA placement. However, the cutoff value of SpO_2 or any other oxygenation parameter has not been determined. In this pilot study, we selected SpO_2 change as one of the predictors for LMA placement failure. Due to the immaturity of respiratory control in children, the high flow resistance of the airways, rapid airway collapse, low gas exchange surface of the lungs, faster oxygen desaturation, and the potential for bradycardia and cardiac arrest as a result of very short-term hypoxia, our study was conducted over three respiratory cycles. In the study population, there was no significant change in SpO_2 levels, and it was determined that SpO_2 levels were an inappropriate predictor for the study group. Similarly, we believe that the $EtCO_2$ change, which we maintained within normal limits for ethical and safety reasons, cannot be a predictor for LMA placement, despite the fact that $EtCO_2$ increased statistically significantly compared to the beginning of the study, as hypercarbia that may transpire following anesthesia induction can lead to severe complications, particularly in children.[17]

The authors of a study that examined the perioperative risk factors of first-attempt LMA placement failure in 461 adult patients undergoing general anesthesia defined LMA placement failure as a severe air leak (>20% VT) or high airway pressure (peak pressure >25 cm-H_2O).[18] Again, in a study that compared two distinct supraglottic airways (SGA) in adult patients, excessive placement of the supraglottic airway device was defined as a minimum expiratory tidal volume of 6 ml/kg during controlled ventilation without oropharyngeal leak or gastric insufflation, and a peak airway pressure of less than 17 cm-H_2O.[19] The optimal peak airway pressure for successful LMA placement in children is unclear. Gursoy et al.[20] determined that the airway leak pressure in pediatric patients was 17 mbar following the appropriate placement of the LMA. Another study compared two different appropriately placed SGAs in pediatric patients and determined that the LMA airway pressure should be 15.3±3.4 cmH_2O to attain the desired VT.[21] While mean airway pressure for SGA's can change according to study population, SGA size, cuff pressure and fresh gas flow used during measurements,[22] the cutoff value for LMA placement failure in our study was established as the peak airway pressure exceeding 13 cm-H_2O after the LMA cuff was inflated to the manufacturer's recommended size and volume. The airway leak pressure was not assessed in the study, as the detection of an airway leak through listening after the initial LMA application was deemed an unsuccessful LMA application. A cutoff of 7 ml was established for airway loss volume in our study population.

Failure to position the LMA on the initial attempt resulted in additional airway attempts. Consequently, patients with failed LMA placement on the first attempt had an increase in postoperative airway problems due to potential upper airway injury. None of these complications, however, resulted in any severe complications.

After LMA placement, adequate sealing allows effective positive pressure ventilation without leakage. Prevents gastric air insufflation. Guarantees adequate ventilation. Increased airway pressures are also associated with increased airway and lung injury in patients with LMA placement.[23] There was no statistically significant difference in postoperative airway complications of airway leakage or airway pressures between the groups with and without successful LMA placement. This may be due to the limitation of the study to 3 respiratory cycles to prevent possible hypoxia and hypercarbia.

Limitations

The study has several limitations. Initially, the variables we identified as predictors, and our results may have been influenced by the definition of the groups based on observational data. Secondly, the examination findings were used to assess the difficulty of airway access in children. Nevertheless, the child's complete orientation is necessary to evaluate other challenging airway markers, such as Mallampati. This may have restricted by the age distribution of the study group. Thirdly, fiberoptic imaging has been recommended in recent studies to ensure the successful placement of LMAs. We refrained from employing a fiberoptic imaging technique in our patients because it had the potential to influence the data we intended to measure. Lastly, the study method was designed to include three respiratory cycles, as the study population would experience severe complications as a result of uncontrolled fluctuations in SpO_2 and $EtCO_2$ levels. Consequently, the authors-maintained control over the variations in SpO_2 and $EtCO_2$. This may have restricted the potential of these two parameters to determine.

CONCLUSION

Objective data are needed to evaluate the safety and clinical performance of the produced supraglottic airway devices. The study showed that airway leakage and peak airway pressure can be used for LMA placement success in children. However, although statistically significant, the specificity and sensitivity of these two parameters are low. Therefore, we think that studies planned with large populations can help increase the safety and clinical.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of the Samsun University Clinical Researches Ethics Committee (Date: 23.08.2023, Decision No: 2023/15/13).

Informed Consent

Written informed consent was obtained from all parents of patients before enrollment.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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