Original Article

Comparison between three-way and standard laryngeal mask airways for children with pulmonary disorders undergoing diagnostic endoscopies

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ABSTRACT

Objective: To compare the safety and efficacy between a three-way laryngeal mask airway (TLMA) and a standard laryngeal mask airway (SLMA) in children with pulmonary disorders.

Methodology: We retrospectively analyzed 60 pediatric patients with pulmonary disorders who had surgical procedures with general anesthesia (oxygen flow rate: 1L/min) and volume control ventilation. Among the patients, 42 were inserted with TLMA (group T) and 18 were administered with SLMA (group S). Several parameters were obtained before, during and after the endoscopic procedure.

Results: Ease of insertion and the conditions during insertion were comparable in both groups. There were no significant differences between the two groups regarding changes in hemodynamic and blood gas parameters. However, patients in group S spent significantly longer time in surgery (group T: 35 ± 24 min compared with group S: 53 ± 31 min, $P < 0.05$) and ventilated (group T: 52 ± 26 min compared with group S: 68 ± 28 min, $P < 0.05$) than those in group T.

Conclusions: TLMA can be considered more effective for ventilation in children with pulmonary disorders who are undergoing general anesthesia.

KEYWORDS: Laryngeal mask airway, General anesthesia, Pulmonary disorders, Children.

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INTRODUCTION

The laryngeal mask airway (LMA) is a valuable supraglottic airway device used for anesthesia and airway support.[1,2] However, there are several limitations for using the standard LMA (SLMA) for pediatric patients. One of the major concerns is its low-pressure seal that is not resistant to high positive pressure ventilation (PPV). This might lead to a risk of gas leakage into the stomach with subsequent gastric distension and regurgitation.[3-5]

The more recently introduced ProSeal laryngeal mask airway (PLMA) has modified features and results in a better seal with periglottic tissues.[6,7] Studies have found that the PLMA formed a more effective seal than the SLMA and facilitated gastric tube placement, which could improve protection

against aspiration.[6] However, without a three-way connector, LMA and PLMA cannot serve as a conduit for delivery of the endoscope to the trachea and lung when mechanical ventilation is used. A new type of LMA with a three-way connector allowing the implantation of various endoscopies is therefore needed, especially for children with pulmonary disorders.[8]

Herein, we describe a new type of LMA incorporating a specific three-way (a 45 degree angle of the three-way) connector to the end of the 15-mm connector of the PLMA (termed a three-way laryngeal mask airway, TLMA). The remaining connector of the three-way connector is sealed and can be connected to an endoscope when necessary. As a part of the 3-way device, the 15-mm connector can be used for ventilation during surgery by connecting to a life-support machine (Fig.1).

METHODOLOGY

Patients: We analyzed 60 ASA physical status 1-3 pediatric patients with pulmonary disorders who had surgical procedures with general anesthesia and mechanical ventilation in our hospital between June 2005 and May 2010. The patient inclusion criteria were: 1) age ≤ 14 years old; and 2) use of general anesthesia and TLMA or SLMA ventilation management. The exclusion criteria were: 1) patients with laryngeal mask contraindications and mouth, pharynx, and throat pain; 2) children with reactive airway diseases; 3) age >14 years; 4) unsuitable for use of the LMA; and 5) other airway diseases. All patients' legal guardians decided to choose TLMA (group T) or SLMA (group S). The causes for surgery for 42 patients in group T and for 18 patients in group S are shown in Table-I. The clinical features of all patients are summarized in Table-II.

Procedures: In the operating room, patients were monitored by electrocardiogram, systolic and diastolic blood pressure (SP and DP), heart rate (HR) and saturation of peripheral oxygen (SpO_2; GE DASH 4000 monitor, USA). Patients in group T and in group S were inserted with a TLMA or SLMA, respectively. Mechanical ventilation was administered through the 15-mm connector to the TLMA and a three-way connector to the SLMA. The size of the TLMA and the SLMA selected are shown in Table-III. The tidal volume (V_T) of 8-12 mL/kg was chosen in an attempt to avoid gastric insufflations. Leak detection was monitored below a peak airway pressure of 20 cm H_2O (P_{peak} set as ≤ 20 cm H_2O, maintained between 10 to 15 cm H_2O during surgery). Volume was added to the cuff to achieve an intracuff pressure of 50-60 cm H_2O. Anesthesia was maintained with fentanyl 5.0 μg/kg^{-1}·h^{-1} and vecuronium bromide 0.08 mg/kg^{-1}·h^{-1} (with the exception of patients with airway foreign bodies, for whom muscle relaxant is contraindicated). HR, blood pressure (SP and DP) as well as SpO_2 were documented before anesthesia (T_0) and during insertion (T_1), 3 (T_2) and 10 minutes (T_3) during surgery, and after the procedure (T_4). P_{peak}, V_T, and end-tidal carbon dioxide tension ($PETCO_2$) were recorded at T_1, T_2, T_3 and T_4. Arterial blood specimens were taken at T_0, T_1, T_2, T_3, and T_4 for blood gas analysis.

Statistical analysis: Data are expressed as mean ± standard deviation (SD), or median and range as appropriate. Data were analyzed by the unpaired Student's *t*-test or ANOVA using SPSS 10.0 statistical software package (SPSS, Chicago, IL, USA). $P<0.05$ indicates a significant difference.

Table-I: The causes for surgery in the 42 patients in group T and in the 18 patients in group S.

	Group T					*Group S*				
Age (years)	*0-1 (n)*	*1-3 (n)*	*3-7 (n)*	*> 7 (n)*	*Total (n, %)*	*0-1 (n)*	*1-3 (n)*	*3-7 (n)*	*> 7 (n)*	*Total (n, %)*
Inflammation	3	8	6	4	21 (50)	1	3	1	1	6 (33.3)
Airway foreign bodies	1	3	0	1	5 (11.9)	1	1	1	0	3 (16.7)
Development deformity	2	0	0	0	2 (4.8)	1	0	0	0	1 (5.6)
Trachea tumor or tracheal stenosis	1	1	2	1	5 (11.9)	0	1	1	0	2 (11.1)
Tuberculosis	0	1	1	0	2 (4.8)	0	1	0	1	2 (11.1)
Bronchiectasis	0	1	1	0	2 (4.8)	0	0	1	0	1 (5.6)
Tracheomalacia	1	1	0	0	2 (4.8)	1	1	0	0	2 (11.1)
Pulmonary hemorrhage	1	0	1	0	2 (4.8)	0	0	1	0	1 (5.5)
Unknown	1	0	0	0	1 (2.3)	0	0	0	0	0 (0.0)
Total (n, %)	15 (35.7)	11 (26.2)	6 (14.3)	42 (100)		4 (22.2)	7 (38.9)	5 (27.8)	2 (11.1)	18 (100)

Table-II: The clinical features of all patients.

Variables	*Group S (n = 18)*	*Group T (n = 42)*
Age (months)	56.7 ± 25.8	58.4 ± 24.3
Gender (n, %)		
Male (n, %)	11 (61.1)	25 (59.5)
Female (n, %)	7 (38.9)	17(40.5)
Body weight (kg)	21.8 ± 7.9	22.2 ± 8.3
ASA physical status		
I (n, %)	9 (50.0)	22 (52.4)
II (n, %)	8 (44.4)	17 (40.5)
III (n, %)	1 (5.6)	3 (7.1)
Concomitant disease		
Cardiovascular diseases (n/%)	0 (0.00)	1 (2.38)
Abdominal diseases (n/%)	1 (5.56)	2 (4.76)
Hematologic diseases (n/%)	1 (5.56)	1 (2.38)
Airway diseases (n/%)	0 (0.00)	2 (4.76)
Neuromuscular diseases (n/%)	0 (0.00)	1 (2.38)
Types of operation		
Trachea tumor resection (n/%)	2 (11.1)	5 (11.9)
Implant of tracheal stent or balloon dilatation (n/%)	2 (11.1)	4 (9.52)
Airway foreign body extraction (n/%)		3 (16.7) 5 (11.9)
Bronchoalveolar lavage (n/%)	8 (44.44)	21 (50.0)
Lung abscess or tuberculosis focal debridement surgery (n/%)	1 (5.56)	3 (7.14)
Lung hemostasis (n/%)	1 (5.56)	2 (4.77)
Fiberoptic bronchoscopy or strip biopsy (n/%)	1 (5.56)	2 (4.77)
Success in insertion rate		
Success insertion at the first attempt (n/%)	16 (88.9)	38 (90.5)
Success insertion at the second attempt (n/%)	2 (11.1)	4 (9.5)
Operation duration (min)	53 ± 31	35 ± 24*
Ventilation duration (min)	68 ± 28	52 ± 26*
Hospital stay (days/range)	5 (3-9)	5 (3-10)
Postoperative complications		
Aspiration	0 (0.00)	0 (0.00)
Sore throat	0 (0.00)	0 (0.00)
Intraoperative awareness	0 (0.00)	0 (0.00)
Larynx edema	0 (0.00)	0 (0.00)
Subglottic edema	0 (0.00)	0 (0.00)
Paralysis of vocal cord	0 (0.00)	0 (0.00)
Hoarseness	1 (5.56)	2 (4.77)
Gaseous distention	0 (0.00)	0 (0.00)

* Indicates a significance difference between two groups ($P < 0.05$).

RESULTS

The clinical features of all patients in the two groups are shown in Table-II. We found that, compared to those in group T, patients in group S were in surgery for a significantly longer time (group T: 35 ± 24 min compared with group S: 53 ± 31 min, $P < 0.05$) and spent longer time ventilated (group T: 52 ± 26 min compared with group S: 68 ± 28 min, $P < 0.05$). However, there were no significant differences between the two groups with respect to clinical characterizations.

Table-III: The size of SLMA for patients.

SLMA size	*Body weight (kg)*	*Patients*
1	< 5	Infant
2	10-20	Children
2.5	20-30	Children
3	> 30	Children

The first-attempt success rate for inserting the TLMA was 90.5% (38/42) of patients, compared to 88.9% (16/18) for the SLMA. However, there was no significant difference in the overall success rate at inserting the devices between the TLMA and the SLMA groups ($P > 0.05$). There was no cough, laryngospasm, or bronchospasm during insertion in either group. Compared to pre-insertion, the SpO_2 in both groups was significantly elevated during and after LMA insertion ($P < 0.05$; all $SpO_2 > 95\%$). There were no significant differences in either HR or blood pressure at any time point between the two groups (Table-IV). While there were no significant differences during and after LMA insertion in either group regarding V_T, P_{peak}, or end-tidal carbon dioxide tension ($PETCO_2$; Table-V, $P > 0.05$), the blood gas analysis results showed that

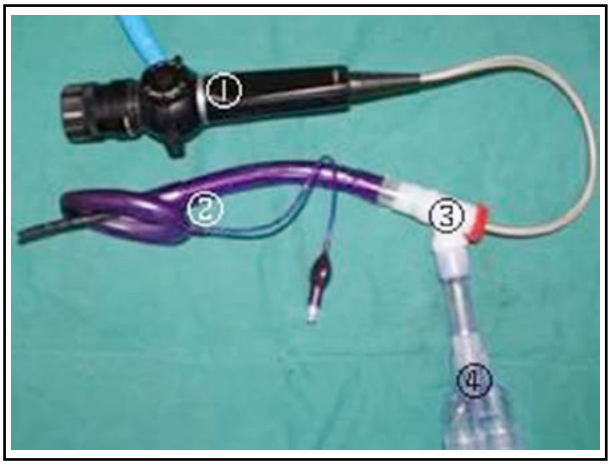

Fig.1: The three-way laryngeal mask airway connects to a life-support machine.
(1) Fiberoptic bronchoscopy;
(2) Laryngeal mask airway (LMA);
(3) Three-way connector;
(4) Connected to a life-support machine.

Table-IV: The comparisons of HR, SP, DP, and SpO2 at different time point between two groups.

Parameters	*Group*	*n*	T_0	T_1	T_2	T_3	T_4
HR (times/min)	S	18	111.2 ± 10.5	104.0 ± 8.0	105.2 ± 10.0	106.0 ± 10.6	107.5 ± 12.6
	T	24	110.6 ± 10.1	105.2 ± 8.2	106.2 ± 11.0	105.6 ± 11.2	108.4 ± 13.4
SP (mmHg)	S	18	115.7 ± 13.2	110.5 ± 12.5	107.5 ± 12.1	110.6 ± 12.4	115.2 ± 14.0
	T	24	116.1 ± 14.0	111.6 ± 11.0	109.7 ± 11.6	111.5 ± 12.1	116.5 ± 13.8
DP (mmHg)	S	18	73.2 ± 8.4	70.3 ± 7.8	71.3 ± 6.7	72.2 ± 6.6	72.9 ± 7.3
	T	24	74.0 ± 8.5	69.5 ± 6.8	70.3 ± 6.5	71.8 ± 6.9	74.1 ± 7.7
SpO2 (%)	S	18	90.4 ± 5.1	97.4 ± 2.2 *	98.2 ± 1.5 *	98.7 ± 1.0 *	98.3 ± 1.0 *
	T	24	91.0 ± 5.0	97.8 ± 2.0 *	98.8 ± 1.5 *	98.9 ± 1.0 *	98.8 ± 1.1 *

* Indicates a significance difference as compared to T0 ($P < 0.05$).

partial pressure of CO_2 in arterial blood ($PaCO_2$), partial pressure of O_2 in arterial blood (PaO_2), and SaO_2 were all significantly improved after LMA insertion and mechanical ventilation (Table-VI, $P < 0.05$; compared with T_0). More importantly, the SpO_2 of 40 patients in group T (40/42) and 13 in group S was maintained >95% throughout the surgery ($P < 0.01$; 95.2% compared with 72.2%).

DISCUSSION

The TLMA has a three-way function: one end comprises the laryngeal mask body, a second end is covered by a sealing cap in which flexible fiberoptic bronchoscopes and other endoscopes can be inserted, and the third end is a 15-mm standard interface port that connects to an anesthesia machine or ventilator. Fig.1 shows a 45 degree angle of the three-way, which may lead to an increase in airway resistance as the reviewer expected. However, in the present study, we used an enlarged inflatable cuff to reduce the airway resistance, and we observed no significant increase in the airway resistance during the surgical procedure in our study. Manual or machine-controlled ventilation can be implemented during endoscopic surgery.

The Chinese Medical Association recommends a V_T of 7-10 cc/kg for pulmonary disease, and in China, 8 cc/kg is usually used for children. In the present study, 8 cc/kg was used for most cases with no remarkable adverse effects. We even increased the V_T to 10-12 cc/kg for 60-90 s when reducing the oxygen concentration in the airway during the operation was required. We believe that this increased the oxygen capacity in patients to maintain $SpO_2 \geq 95\%$, thereby facilitating the surgical process and diminishing post-surgery complications. In our study, the airway pressure and blood gas data showed that results were favorable without major accompanying complications; this indicates the feasibility of using the relatively higher V_T. However, more studies are required to confirm this.

The present results show that TLMA is eminently capable of solving the problem of airway management during airway surgeries, and it is unique in airway management during the surgery of pulmonary disorders. We compared a modified LMA that incorporated a specific three-way connector with the SLMA in pediatric patients with pulmonary disorders. While the conditions during insertion were similar for both devices, the patients in group S required significantly longer time in surgery and under ventilation than those in group T. We believe that the TLMA was a better and more effective airway device for ventilation in children with pulmonary disorders undergoing general anesthesia compared with the SLMA. Our results show that although there was a small difference in successful insertion rate between the TLMA and the SLMA groups on the first attempt at application, overall no significant differences in successful

Table-V: Comparisons of VT, Ppeak, and ETCO2 at different time point between two groups.

Parameters	*Group*	*n*	T_1	T_2	T_3	T_4
VT (mL)	S	18	222.1 ± 124.0	219.5 ± 126.6	218.8 ± 124.6	224.5 ± 127.0
	T	42	219.6 ± 121.2	223.2 ± 125.8	221.8 ± 125.5	225.3 ± 130.4
Ppeak (cm H2O)	S	18	16.5 ± 2.3	16.4 ± 2.4	16.5 ± 2.5	16.3 ± 2.1
	T	42	15.2 ± 2.1	15.3 ± 2.2	15.6 ± 2.3	15.5 ± 2.2
PETCO2 (mmHg)	S	18	42.3 ± 3.7	41.7 ± 3.3	39.6 ± 3.6	39.5 ± 3.8
	T	42	42.8 ± 3.1	41.5 ± 3.5	39.7 ± 3.2	37.8 ± 3.3 *

* Indicates a significance difference as compared toT1 ($P < 0.05$). VT: tidal volume, Ppeak: Peak inspiratory airway pressure, PETCO2: end-expired CO2 tension.

Table-VI: Comparisons of blood gas analysis at different time point between two groups.

Parameters	*Group*	*n*	T_1	T_2	T_3	T_4
pH	S	18	7.32 ± 0.10	7.33 ± 0.08	7.37 ± 0.06	7.41 ± 0.06
	T	40	7.31 ± 0.08	7.34 ± 0.07	7.38 ± 0.07	7.43 ± 0.04
PaCO2 (mmHg)	S	18	45.5 ± 3.8	44.7 ± 3.5	41.3 ± 3.1 *	39.3 ± 2.5 *
	T	40	46.1 ± 4.2	44.8 ± 3.3	41.1 ± 3.2 *	38.5 ± 2.5 *
PaO2 (mmHg)	S	18	85.6 ± 11.5	147.4 ± 21.3 *	148.5 ± 22.7 *	138.0 ± 20.6 *
	T	40	82.8 ± 14.1	189.0 ± 24.9 *,#	198.6 ± 30.7 *,#	191.9 ± 27.3 *,#
SaO2 (%)	S	18	86.9 ± 4.0	95.0 ± 1.7 *	97.0 ± 1.4 *	98.2 ± 1.0 *
	T	40	87.7 ± 3.5	96.0 ± 1.5 *	98.0 ± 1.3 *	98.5 ± 1.0 *

* Indicates a significance difference as compared to T0 and group s ($P < 0.05$). The data of two patients in groups T were unavailable. PaCO2: arterial partial pressure of carbon dioxide, PaO2: arterial partial pressure of oxygen.

insertions were observed. Possible reasons for the difference in first-attempt insertion remain unclear; but the personal experience of the staff, patient conditions during procedures, and the number of different cases may account for this. More study may be required to confirm this.

When LMA is used, if SpO_2 drops to <85% during the surgery the endoscope has to be removed and reinserted after SpO_2 returns to 95%-100%. This may lead to an increase in time in surgery and frequency of LMA insertion. One of the major modifications of the TLMA is the enlargement of the inflatable cuff. This not only provides implantation of a tracheal stent or balloon dilatation, but also facilitates ventilation during surgery. TLMA reduces the time of surgery and ventilation by retaining the endoscope. Another modification of the TLMA is a shortened flexible airway tube. The aim of this modification is to facilitate endoscopic access of the trachea and lung, particularly in pediatric patients.

We believe that the TLMA provides a new strategy for airway management in pediatric airway surgery by allowing the implantation of various endoscopies.[9] As shown in Table-VI, although there was no significant difference in $PaCO_2$ between the two groups, and the excellent ventilation characteristics of SLMA and TLMA are maintained during the surgeries, patients in group S were in surgery and under ventilation for a significantly longer time those in group T. This suggests the TLMA has a better clinical value in pediatric airway surgeries. In the present study, the TLMA was applied at the first attempt in 90.5% patients, and 9.5% patients were inserted at the second attempt. The insertion of TLMA can be guided by the fiberoptic bronchoscope.[10,11] There was no cough, laryngospasm, or bronchospasm throughout the procedure.

During the surgery, SpO_2 in two patients less than one year old was decreased to 85%. We speculated that this might be because of the small trachea or inflammation in the respiratory tract. This problem was resolved by removing the endoscope out of the glottis and then resuming when SpO_2 returned to 95%-100%. At the time of the TLMA removal, transient laryngospasm was noted in one patient, which was probably due to inflammation of the respiratory tract. After removal of the TLMA, two patients had transient hoarseness that resolved spontaneously within two days. Endoscopy is an important tool in the diagnosis and treatment of airway diseases. We believe that TLMA may be an effective device to resolve the insufficient ventilation that is always occurring during endoscopic surgery.[12]

Considering the possibility of gas leak during the surgery, we did not use sevoflurane to maintain inhalation anesthesia. Alternatively, a paralyzing agent such as vecuronium may facilitate the insertion of the LMA and maintain the airway pressure at a low level. Using the classic LMA under mechanical ventilation, stomach distension is inevitable especially in young children. However, in the present study we maintained the airway pressure between 10 and 15 cmH_2O, thereby reducing gastrointestinal complications. In conclusion, our results show that the TLMA is a more effective airway device for ventilation in children with pulmonary disorders undergoing general anesthesia.

We conclude that the three-way laryngeal mask airway (TLMA) can be safely applied in children with pulmonary disorders undergoing diagnostic endoscopies and is more effective than the standard laryngeal-mask airway (SLMA).

Ethical approval: This study was approved by the Ethics Review Board of 303 Hospital of PLA.

Conflict of Interest: The authors have declared that no conflicts of interest exist.

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Jun Zhong: Experiments, manuscript writing.
Chaokun Quan: Project design, experiments.