ORIGINAL ARTICLE

Comparison of the effect of LMA and ETT on ventilation and intragastric pressure in pediatric laparoscopic procedures

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ABSTRACT

Aim. The aim of our study was to compare classic laryngeal mask airway (LMA-C) with the endotracheal tube (ETT) in pediatric laparoscopic surgery to evaluate the intragastric pressures (IGP) using intragastric pressure monitoring. We also sought to investigate the related influence on respiratory parameters.

Methods. The Ethics Committee of the Health Institution approved the study protocol. A total of 40 patients, ASA I-II, three and a half months to 12 years old were included in this randomized study. Two study groups were formed: the ETT group and the LMA-C group. A nasogastric tube was inserted following induction to evacuate any intragastric gas and fluid before application of either LMA-C or ETT. The change in IGP was measured with a transducer, which was attached to the nasogastric tube. IGP, peak airway pressures (PAP), SPO_2 and $ETCO_2$, levels were recorded. Repeated ANOVA measures were used to evaluate the change in IGP, PAP, SPO_2 and $ETCO_2$ times in both groups.

Results. The change in IGP was insignificant among the groups except at 15 and 30 minutes ($P<0.05$). The changes in PAP, SPO_2, and $ETCO_2$ levels were insignificant.

Conclusion. The perioperative intragastric pressure evaluation failed to show any significant change in intragastric pressures and ventilation parameters due to the application of LMA-C in this study. We advocate LMA-C application as a feasible anesthetic device in pediatric laparoscopic surgery.

Key words: Laparoscopy - Laryngeal masks - Intragastric pressure.

Laryngeal mask airway (LMA, Classic™, LMA Comp., Henley-on-Thames, UK) is a useful airway device for patients under anesthesia. It is also used extensively in routine pediatric anesthesia practice. It has been shown that the risks of unprotected airway hypoventilation and aspiration due to gastric distension are no more frequent when LMA is ompared with with ETT in laparoscopic surgery.[1-3]

Some studies suggest that LMA may be safely used in pediatric laparoscopic surgery, however, it is not recommended during prolonged procedures or in patients with limited cardiorespiratory reserve.[4, 5] The perioperative management of children undergoing laparoscopic surgery is essentially identical to that recommended for other intra-abdominal procedures, except for two factors that may challenge anesthesia. These factors are creation of pneumoperitoneum and positioning of the patient. Pneumoperitoneum is associated with absorption of insufflated carbon dioxide and elevation of intra-abdominal pressure. Proper positioning is necessary for the optimal exposure of intra-abdominal structures in some procedures. The risk of regurgitation and aspiration is expected to increase during laparoscopy due to the Trendelenburg position, or compression on the abdominal wall and peritoneal stimulation by the surgeon, which may further increase intra-abdominal pressure. Elevated intra-abdominal pressure results in a multitude of detrimental pathophysiological effects, such as early closure of small airways leading to increased peak airway pressure, while elevated $ETCO_2$ elicits hypoxemia.[6, 7]

The close relationship between the intragastric and intra-abdominal pressure gradients has recently been demonstrated. Intra-abdominal pressure monitoring is a simple and effective method that correlates well with indirect gastric pressures.[8] These pressure gradients may be measured with the help of a transducer connected to a nasogastric tube, which is placed in the stomach.[9] An increase in intra-abdominal pressure will be reflected as an increase in intragastric pressures. To the best of the authors' knowledge, intragastric pressure monitoring has not been used in children and/or with LMA-C as a parameter in any laparoscopic procedure. In this prospective randomized controlled study, the aim was to compare the LMA-C to the ETT in pediatric laparoscopic surgery, to evaluate intragastric pressure by using intragastric pressure monitoring and to investigate its influence on respiratory parameters.

Materials and methods

In this prospective randomized study, approved by our University Institutional Research Board, written informed consent was obtained from the parents of each patient. A total of 40 children ages 3/12-12 years, in ASA physical status I-II, who were undergoing laparoscopic inguinal hernia repair were randomized to either the LMA-C or the ETT groups (Endotest, Rüsch Inc., Germany) group.

Subjects

All patients were randomized to one of the airway management groups (LMA-C or ETT), using the sealed-envelopes method. The method of airway management was written on a piece of paper and sealed in opaque envelopes. The type of airway management was decided when one of the authors who was not involved in the application of the airway (KT) picked up an envelope from a basket.

The exclusion criteria included patients who had histories of gastroesophageal reflux, hiatal hernia, upper respiratory infection or diabetes mellitus.

An elective laparoscopic inguinal hernia repair was performed on all patients under general anesthesia in the supine position. Children fasted with clear liquids for four hours before their scheduled time of surgery. Rectal midazolam 0.6 mg kg^{-1} was used for premedication. Placement of the electrocardiogram, pulse oximeter and non-invasive blood pressure monitoring were followed by preoxygenation. Preoxygenation was maintained for three minutes before induction. Anesthesia was induced with 8% sevoflurane inhalation in 33% oxygen and 66% nitrous oxide; 0.08 mg kg^{-1} vecuronium was administered intravenously. Anesthesia was maintained with 2% sevoflurane, nitrous oxide 66% and oxygen 33%.

Measurement of the intragastric pressure

An NG tube (8-10 G) was inserted following induction to evacuate any intragastric gas and fluid before application of either LMA-C or ETT. The position of the NG tube was confirmed by epigastric auscultation and was secured in place. A beginning base pressure was obtained following evacuation and positioning. A three-way stopcock was attached between the NG tube and a standard pressure monitoring line. A syringe was attached to the remaining port of the stopcock. A small volume of sterile saline was instilled to ensure a continuous column of fluid between the stomach and the pressure transducer in the closed pressure monitoring system. Our reference point was the intersection of the anterior axillary line with a transverse line at the level of the xiphoid. This apparatus is based upon the principles of hydrostatic pressure measurement as in Khron's study.[9] We measured the change in IGP by means of this pressure transducer.

Airway management

Inadvertent use of bag or mask ventilation was avoided during the time between induction and insertion of LMA-C or ETT. Selection of the appropriately sized LMA-C was in accordance with routine practice. (Instruction for weight: Size

1 for infants <5 kg, size 1.5 for infants 5-10 kg, size 2 for patients 10-20 kg, size 2.5 for patients 20-30 kg). The clinically correct position of the LMA-C was confirmed by the absence of leak upon auscultation of the epigastrium and neck, audible sound escaping from the mouth and adequate chest expansion during manual ventilation. A pressure monitor (Endotest) was used and intracuff pressure was maintained at 60 cm H_2O with the LMA-C.[10]

Selection of the appropriately sized ETT was in accordance with the standard protocol for uncuffed tubes; (age/4) + 4.5. A minimum leak pressure of 15-25 cm H_2O was accepted for an uncuffed ETT.[11, 12] If an excessive leak was detected, the ETT was replaced by one that was larger in size. Correct positioning was confirmed by auscultation and capnography.

We performed the leak test *via* manometric stability: The oropharyngeal leak pressure was measured by closing the expiratory valve of the circle system at a fresh gas flow of 3 L·min?1 and noting the airway pressure at which equilibrium was reached. The range of airway pressure during pressure leak test was recorded during ventilation. It was ensured that the PAP was nearly double the oropharyngeal leak pressure at the time of the leak test. Patients were paralyzed during the tests and underwent manually assisted ventilation. The intracuff pressure was adjusted to and maintained at 60 cmH_2O using a Digital cuff pressure monitor.[10, 13] The average value of oropharyngeal leak with an intracuff pressure of 60 cm H_2O was 12.5 cm H_2O.

The presence of a gas leak was detected as an audible sound escaping from the mouth, auscultation of the epigastrium or neck, and bubbling of lubricant placed on the mask.

Ventilation parameters were initially set at a tidal volume of 10 mL kg^{-1} and rate of 15 min^{-1}. Respiratory rates were adjusted according to changes in $ETCO_2$ with fresh gas flow at 3 $Lmin^{-1}$ maintenance levels. Peritoneal insufflation pressure was preset and maintained at 8-10 mmHg of CO_2. IGP, PAP, SPO_2 and $ETCO_2$ were recorded before and during peritoneal insufflation. IGP, PAP, SPO_2 and $ETCO_2$ were recorded every 15 minutes. Peritoneal insufflation and total anesthesia times were recorded.

An SPO_2 value above 94% was accepted as saturation level. For $ETCO_2$ values, the ranges beyond 40 mmHg and 45 mmHg were accepted as upper limits before and after insufflation, respectively.

At the end of the operation Sevoflurane and nitrous oxide were stopped, neuromuscular blockade was reversed and the airway device was removed in the operating room.

Complications (aspiration or regurgitation, etc.) were noted. The presence of coughing, vomiting, laryngospasm, hoarseness and/or sore throat during the first 2 hours after the end of the anesthesia were noted as postanesthesia complications.

The primary outcome measure was determined as change in the intragastric pressure. Secondary outcome measures were PAP, $ETCO_2$, and SPO_2.

The sample size was defined as a difference of 20% from baseline intragastric pressure. For this study, 18 patients per group were required to have a power of 80% and type I error of 0.05.[14-16]

Statistical analysis

SPSS 13.0 was employed for analysis of data. Independent t-test analyses were used for demographic data. We chose to analyze the first 60 min because very few operations lasted longer than 60 min. Repeated ANOVA measures were used to evaluate the change in intragastric pressure, peak airway pressure, SPO_2 and $ETCO_2$ within the allotted time in both groups. The Bonferroni adjustment was used for comparisons across time for all variables; between-group differences were assessed by ANOVA. Continuous categorical variables in the LMA and ETT groups were compared with each other. The data for continuous variables are presented as mean and standard deviation (SD). The data presented in box plots show median and interquartile ranges with outliers. P-values less than 0.05 were set for statistical significance.

Results

In this prospective randomized study, 20 patients were included in the ETT group and 20 patients in the LMA-C group (Table I). We did not observe any difficulties during the intubation or ventilation phase in any of the patients. One case in the LMA-C group was excluded from the

TABLE I.—*Demographic data (Mean±SD).*

	ETT N.=20 Mean±SD	LMA-C N.=19 Mean±SD
Age (months)	47±40	42±34
Weight (kg)	15±6	16±10
Mean anesthetic time (min)	74±35	68±22
The time between anesthesia induction and institution of the pneumoperitoneum (min)	14±4	14±11
Total insufflations time (min)	51±34	52±24

ETT group N.=20; P>0.05; one case of LMA-C group was excluded from the study as laparoscopy was converted to laparotomy (N.=19).

study as laparoscopy was converted to laparotomy. There were no other dropouts from the study for any reason, and all the remaining cases received the intended management.

There were no significant differences in demographic data among the groups (Table I) (P>0.05).

The time to anesthesia induction for the pneumoperitoneum was 14.5±4.8 min in the ETT group, and 14±11.2 min in the LMA-C group. There were no significant differences between the groups (P>0.05).

The change in IGP within each group with respect to time was insignificant (P=0.20). The change in IGP between the groups was insignificant (P=0.9), except for at 15 and 30 min in both groups. ETT group values were lower than those observed in the LMA-C group at 15 and 30s min P<0.05 (Figure 1).

The peak airway pressure levels did not change significantly among the groups with respect to time (P=0.3). The difference in peak airway pressure between the groups was not significant (P=0.2) (Figure 2).

There was no significant difference among the

TABLE II.—*Postoperative complications related to the airway device (ETT /LMA-C).*

	Pre-treatment	Post-treatment	P
Sore throat pc/%	4/20%	2/10%	0.38
CI 95%	2-37	0-24	
Cough pc/%	2/10%	2/10%	0.99
CI 95%	0-23	0-24	
Hoarseness pc/%	0	0	—
CI 95%			
Laryngospasm pc/%	1/5%	0	0.3
CI 95%	0-14		
TOTAL pc/%	7/35%	4/20%	0.3
CI 95%	14-55	2-39	

P<0.05; pc: patient count; CI: confidential intervals of the percentages.

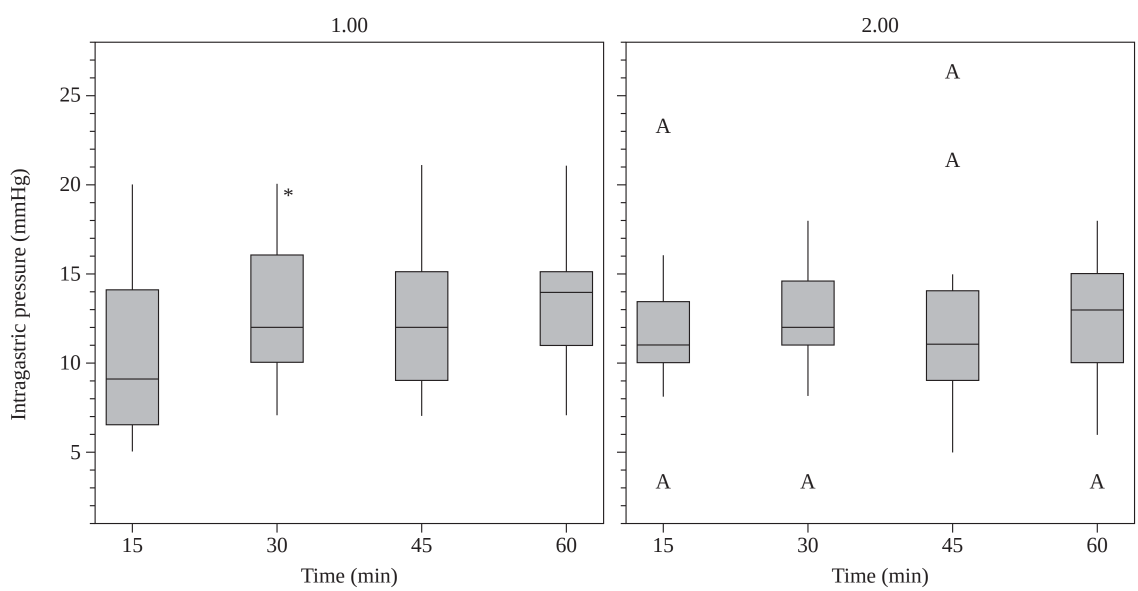

Figure 1.—Intragastric pressure values of cases in time (mmHg). The data presented in box plots show median and interquartile range with outliers. *P<0.05. Group ETT=1; Group LMA=2.

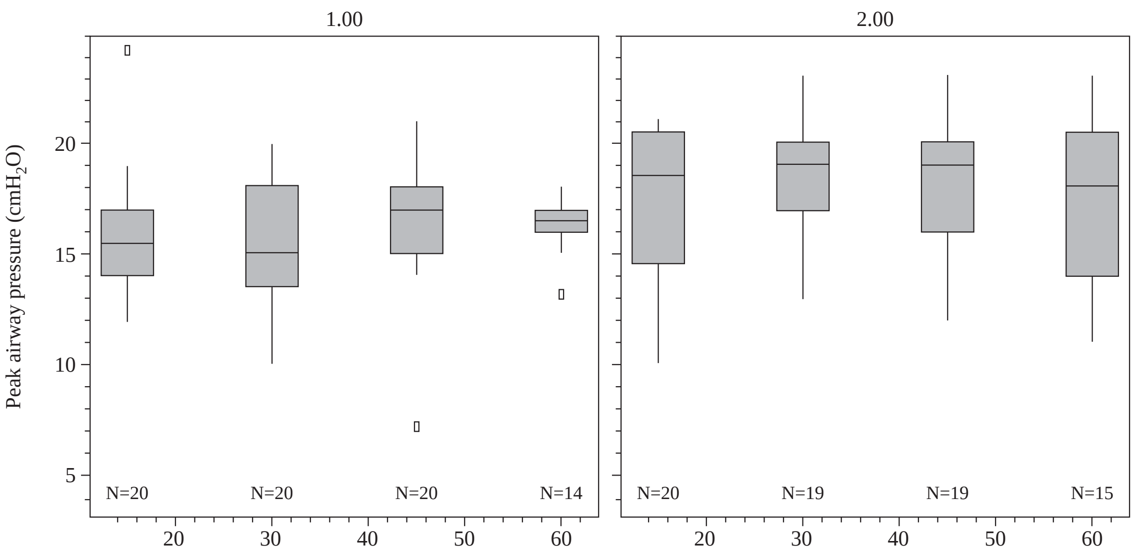

Figure 2.—Peak airway pressure values of cases in time (mmHg). The data presented in box plots show median and interquartile range with outliers. *P<0.05. Group ETT=1; Group LMA=2.

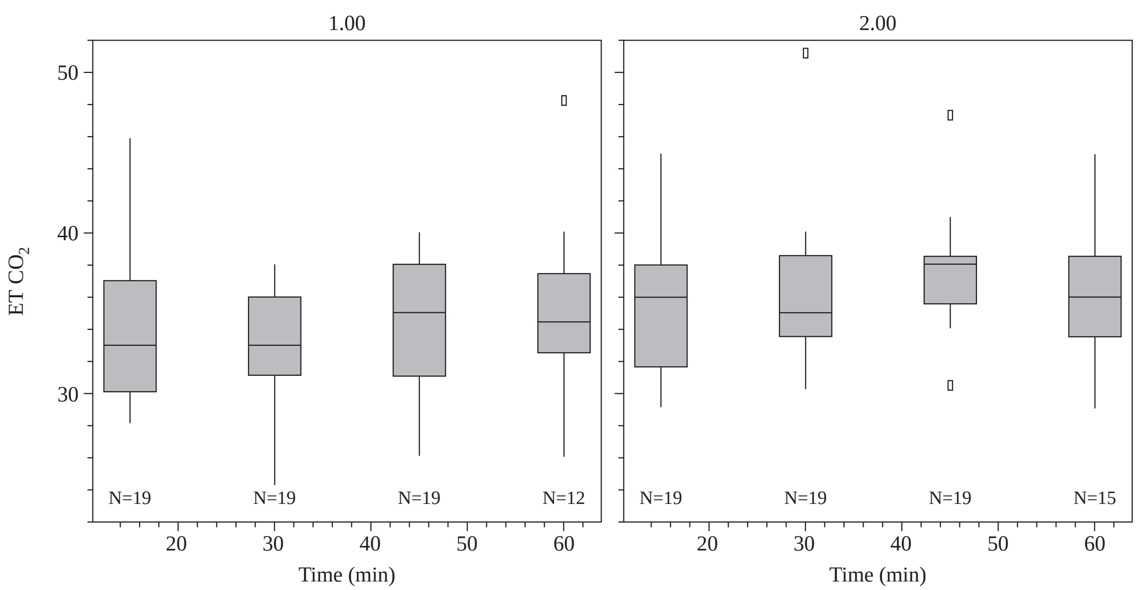

Figure 3.—$ETCO_2$ values in time (mmHg). The data presented in box plots show median and interquartile range with outliers. *P<0.05. Group ETT=1; Group LMA=2. Is this the correct measure? If so, make this consistent anywhere it is used in this paper.

groups for SPO_2 values with respect to time (P=0.053). The difference in SPO_2 values between the groups was also insignificant (P=0.8).

The change in $ETCO_2$ levels within time was insignificant (P=0.08). The difference in $ETCO_2$ levels was also insignificant among the groups (P=0.054) (Figure 3).

The incidence of postoperative complications was higher in the ETT group (Table II). Morbidity due to aspiration or regurgitation did not occur in either group.

Discussion

According to our data, intragastric pressure monitoring proved that the use of LMA-C has no significant adverse effect on gastric distention and related respiratory parameters in pediatric patients undergoing laparoscopic surgery.

In general, endotracheal intubation is a safer method for airway protection. LMA-C has been used as an alternative to endotracheal intubation. Despite distension of the abdomen by gas insufflations, safe use of LMA-C by experienced clinicians in adult laparoscopic surgery has been documented.[1, 2] Maltby *et al.*[1] demonstrated that, in healthy patients in the supine position, a correctly placed LMA-C of appropriate size might be a safe and effective alternative to an ETT for positive pressure ventilation. Nevertheless, gastric distension, pulmonary aspiration of gastric contents, and inadequate ventilation risks should be still considered.[2]

Anesthesia, however, may be challenged by pneumoperitoneum-associated elevation of intra-abdominal pressure in pediatric laparoscopic surgery. Increased intra-abdominal pressure causes changes in pulmonary mechanics. It is known that both elevation of intra-abdominal pressure and Trendelenburg positioning may reduce diaphragmatic excursion and shift the diaphragm in the cephalous direction.[17] Bannister *et al*.[18] showed that pulmonary mechanics change significantly in infants during laparoscopic carboperitoneum, the magnitude of which correlates directly with intra-abdominal pressure and its duration.

Published studies concerning the use of LMA-C in pediatric laparoscopic procedures are rare in the literature.[10, 19] A reliable tool is required for monitoring the correlation of changes in intra-abdominal pressure and its influence on respiratory parameters. Intravesical pressure measurement has long been regarded as a reflection of the actual intra-abdominal pressure and used as a valid parameter. Later, attempts to measure the relationship between intragastric pressures and intra-abdominal pressure in humans have often used the index measurement of intra-abdominal pressure as that recorded either by the pressure monitor built within the high-flow carbon dioxide insufflator during laparoscopy or the intravesical pressure.[20, 21] In recent published studies, intragastric pressures are commonly employed as a surrogate measure of intra-abdominal pressure in respiratory research.[9, 22] However, evidence for the relationship between intragastric pressures and intra-abdominal pressure is conflicting, and neither intragastric pressure nor intravesical measure reliably reflect intra-abdominal pressure.[9, 22] Notably, the operator set the intra-abdominal pressure delivered by the CO_2 insufflator to be between 8 cm and 10 cm H_2O. Intra-abdominal pressure recorded by our system was frequently higher. This reflects the additional intra-abdominal pressure generated during surgical manipulation of the abdomen. Within a subject, the relationship between intragastric pressure and intra-abdominal pressure was consistent. This was reflected by the small coefficient of variation.

We investigated the change in intragastric pressure measurements during positive pressure ventilation through LMA-C as compared with ETT. Maltby *et al.*[1] evaluated the presence of gastric distension as a parameter in a comparative study using ETT and larger-sized LMA-C. In their published study, the recorded gastric distension scores were subject to the surgeon's personal observation.[1] We believe that the mere observation of gastric distension is a rather subjective method and that such observation surely is less reliable when compared with intragastric pressure monitoring as an objective method. To the best of the authors' knowledge,[8] intragastric pressure monitoring has not been used in children and/or with LMA-C as a parameter in any laparoscopic procedure.

The changes in respiratory parameters in our study were similar to those observed in previous published studies.

Hysing *et al*.[23] reported that airway pressure and $ETCO_2$ were observed to increase, especially in the Trendelenburg position, under an intra-abdominal pressure of 10 cm H_2O. Tobias *et al*.[5] reported a statistically insignificant rise in $ETCO_2$, without any change in the SPO_2, in their study concerning laryngeal mask usage in children undergoing laparoscopic procedures. In our study, the rates of change in $ETCO_2$ and SPO_2 were similar and within normal limits.

According to our data, intragastric pressures were increased in both groups during the same period (at 15 and 30 minutes), which was equivalent to the initiation of abdominal insufflations. Peak airway pressure, however, was higher for the ETT group during the period mentioned.

According to our results, we did not observe any data related to air leakage that might affect the respiratory parameters. Sinha *et al*.[10] state that Proseal LMA and ETT are equally effective in providing ventilation and oxygenation without producing clinically significant gastric distension during laparoscopic surgery.

The main concern about LMA-C utilization in laparoscopy is that the associated risks of aspiration may be higher due to gastric distension. Some authors state that the increase in intra-abdominal pressure during laparoscopy may result in an increase in gastroesophageal reflux.[24] Other studies have reported a minimal risk of aspiration pneumonia.[3, 25] A peritoneal insufflation-associated increase in abdominal pressure, however, is also said to cause a reflex increase in tone of the lower esophageal sphincter.[26] The presence of a nasogastric tube, while reducing the potential protection of the upper esophageal sphincter, may further protect the patient from aspiration, permitting frequent suction and removal of gastric fluids and bile. We did not observe any regurgitation or aspiration problems in our study.

Similar to Maltby's study,[1] postoperative airway complications such as sore throat, coughing, hoarseness and laryngospasm were rare during the first two hours after the end of the anesthesia.

Limitations of the study

One of the limitations of our study was that we were not able to detect a significant difference for the regurgitation or postanesthesia complications. The events likely happened rarely, and hundreds of cases might be necessary for the phenomenon to reach statistical significance.

Conclusions

Our study provides strong evidence demonstrating the close relationship between intragastric pressure and intra-abdominal pressure, as previously described by Thurnbull.[8]

These results show that intragastric pressure monitoring is an easy-to-perform and cost-effective method that enables continuous data interpretation for intra-abdominal pressure during laparoscopic procedures. We have observed that LMA-C-associated laparoscopic procedure neither produces a significant increase in intragastric pressures nor deteriorates ventilation parameters.

In conclusion, our randomized, controlled trial demonstrates that correctly placed LMA-C may be a feasible and effective alternative to ETT in healthy children undergoing laparoscopic surgery.

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