SMJ Singapore Medical Journal

Second-generation laryngeal mask airway as an alternative to endotracheal tube during prolonged laparoscopic abdominal surgery: a comparative analysis of intraoperative gas exchanges

Sukhee Park[1], MD, Ja Eun Lee[2], MD, Gyu Sung Choi[3], PhD, Jong Man Kim[3], PhD,
Justin S Ko[2], PhD, Duck Hwan Choi[2], PhD, Gaab Soo Kim[2], PhD

[1]Department of Anesthesiology and Pain Medicine, International St Mary's Hospital, Catholic Kwandong University School of Medicine, Incheon, [2]Department of Anesthesiology and Pain Medicine, [3]Department of Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

Correspondence: Dr Gaab Soo Kim, Professor,Department of Anesthesiology and Pain Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine,
81 Irwon-ro, Gangnam-gu, Seoul 06351, Korea. gskim@skku.edu

Singapore Med J 2021, 1–17
https://doi.org/10.11622/smedj.2021143
Published ahead of print: 7 October 2021

ABSTRACT

Introduction: Despite several advantages over endotracheal tube (ETT), laryngeal mask airway (LMA), which is used in emergencies under difficult airway maintenance conditions, is rarely utilized in prolonged surgery. We compared the variables representing intraoperative gas exchange with second-generation LMA and ETT during prolonged laparoscopic abdominal surgery.

Methods: Prolonged surgery was defined as a surgery lasting more than 2 h. In total, 394 patients who underwent laparoscopic liver resection via either second-generation LMA or ETT were retrospectively analysed. Parameters including end-tidal pressure of carbon dioxide ($ETCO_2$), tidal volume (TV), respiratory rate (RR), peak inspiratory pressure (PIP), arterial partial pressure of carbon dioxide ($PaCO_2$), pH, and ratio of arterial partial pressure of oxygen to fractional inspired oxygen (PFR) during surgery were compared between the two groups. In addition, the incidence of postoperative pulmonary complications (PPC) including pulmonary aspiration was also compared.

Results: The values of $ETCO_2$, TV, RR and PIP during pneumoperitoneum were comparable between the two groups. Although $PaCO_2$ at 2 h after induction was higher in patients with LMA (40.5 vs. 38.5 mmHg, $p < 0.001$), the pH and PFR values of the two groups were comparable. The incidence of PPC was not different.

Conclusion: During prolonged laparoscopic abdominal surgery, the second-generation LMA facilitates adequate intraoperative gas exchange and represents an alternative to ETT.

Keywords: laparoscopic liver resection, laryngeal mask airway, prolonged abdominal surgery

INTRODUCTION

Laryngeal mask airway (LMA) is widely used in many clinical scenarios requiring airway maintenance. LMA is associated with several advantages compared with endotracheal tube (ETT) including ease of insertion, hemodynamic stability at insertion and removal, low pharyngo-laryngeal morbidity, and reduced need for anaesthetics.(1-3) However, the LMA covering the glottis without direct insertion into trachea is a structural limitation, which increases the possibility of inadequate ventilation and oxygenation and the risk of aspiration. Moreover, the prolonged use of LMA may trigger gastric dilatation, which leads to inadequate ventilation and oxygenation.(4,5) Therefore, LMA is indicated for short operations completed within 2 h.(6) The second-generation LMA is a new device designed to compensate the structural shortcomings of classic LMA (CLMA), the initial model of LMA.(2,6,7) It carries an additional port for gastric drainage tube to reduce gastric insufflation and improve airway sealing compared with CLMA.(6,7)

Laparoscopic liver resection (LLR) has become a popular treatment option for liver cancer and is widely performed in many clinical centres currently. The authors have used a second-generation LMA with gastric drainage tube for LLR since November 2017. Although several reports of second-generation LMA during short laparoscopic abdominal surgery such as cholecystectomy are available,(8,9) few studies evaluated the use of such LMA in prolonged laparoscopic abdominal surgery. Thus, we investigated whether second-generation LMA facilitated adequate intraoperative gas exchange during LLR.

METHODS

This study was a retrospective analysis of electronic medical records. The Institutional Review Board of Samsung Medical Center approved this study (SMC 2018-11-093) and waived the requirement for written informed consent. We have used LMA-Protector (LMA® Protector™

Airway, Teleflex, Ireland, PLMA) in LLR since October 31st, 2017. Prior to May 30th, 2017, ETT was inserted in all patients undergoing LLR. We used PLMA without gastric drainage tube between May 30th and October 30th of 2017.

We screened 564 consecutive patients who underwent elective LLR between July 2014 and April 2018 in a single tertiary hospital. We defined prolonged surgery based on surgical duration greater than 2 h. The study included only patients who were administered anaesthesia by the corresponding author or those who were supervised by the corresponding author. Patients who underwent LLR from June 2017 to October 2017 were excluded. We further excluded 2 patients whose LMA was switched to ETT during surgery, 2 patients with failed LMA insertion, 5 patients whose surgery was switched to laparotomy, and 9 patients with incomplete electronic medical records. Among the remaining 394 patients, we compared those who underwent LMA (group L) with those who were treated with ETT (Group E).

All patients fasted for at least 8 h before the surgery. Anaesthesia was induced with thiopental sodium 5 mg/kg, vecuronium 0.1 mg/kg, and sevoflurane. The arterial blood pressure of all patients was monitored, while no central venous line was secured. PLMA insertion was performed only by the corresponding author. The PLMA size was selected according to the manufacturer's weight-based recommendations. We used LMA size 3 for those weighing between 30 and 50 kg, LMA size 4 for those weighing 50-70 kg, and LMA size 5 for those weighing more than 70 kg. We used an ETT measuring 7 mm in internal diameter for women and an 8 mm ETT for men. Effective ventilation was defined based on the following criteria: (1) symmetrical breath sounds, (2) typical square wave pattern of capnography curve, (3) absence of audible leak, and (4) tidal volume (TV) 8 mL/kg (ideal body weight) with a peak airway pressure < 30 cmH$_2$O. PLMA was removed, and ETT was inserted in the absence of effective ventilation.

Volume-controlled ventilation and positive end-expiratory pressure at 6 cmH$_2$O were used for all patients. Fractional inspired oxygen was set to approximately 0.5. The respiratory rate (RR) was adjusted to maintain the end-tidal pressure of carbon dioxide ($ETCO_2$) at 35 to 40 mmHg. We inserted a gastric drainage tube into all patients to ensure adequate LMA insertion, and prevent gastric insufflation during surgery. Vecuronium was continuously infused for muscle relaxation during surgery. Anaesthesia was maintained with isoflurane, and anaesthetic depth was adjusted to maintain a bispectral index between 40 and 60. $ETCO_2$ and ventilator parameters such as TV, RR, and peak inspiratory pressure (PIP) were automatically recorded every 10 min electronically. Arterial blood gas analysis (ABGA) was performed after induction of anaesthesia, every 2 h after induction of anaesthesia. Most patients were transferred to post-anaesthesia care unit after surgery.

We reviewed data pertaining to $ETCO_2$, TV, RR, and PIP after induction of anaesthesia (T1), after initiation of pneumoperitoneum (T2), before end of pneumoperitoneum (T3), and end of surgery (T4). The partial pressures of carbon dioxide ($PaCO_2$), pH and partial pressure of oxygen (PaO_2) were also reviewed based on ABGA results. The ratio of PaO_2 to fractional inspired oxygen (PFR) was calculated to compare the oxygenation levels. Postoperative pulmonary complications (PPCs) including pulmonary aspiration were reviewed until seven days after surgery, and defined based on the previously published study.(10) PPC was a composite of pleural effusion, atelectasis, and respiratory infection. Pulmonary aspiration was defined as pulmonary infiltration on chest X-ray associated with regurgitation of gastric contents.(11) The primary outcome was the difference in $ETCO_2$ during surgery between the two groups according to airway device.(12-14) Ventilator parameters, ABGA results during pneumoperitoneum, and PPC were also compared between the two groups according to airway device.

Continuous variables were summarised as mean (standard deviation) or median (interquartile range), and categorical variables were presented as frequency (%). The distribution of continuous variables was analysed using Kolmogorov-Smirnov test. Demographics and perioperative parameters were compared using Student's t-test or Mann-Whitney test for continuous variables and chi-square test or Fisher's exact text for categorical variables. Baseline differences in the duration of anaesthesia and pneumoperitoneum in the two groups were adjusted via analysis of covariance or linear mixed models using age, body mass index, albumin, crystalloid infusion rate (mL/kg/h), and duration of anaesthesia and pneumoperitoneum as covariates. The linear mixed model was used with time, group, and the time × group interaction as fixed factors, and patients as random factors. All reported *p*-values were two-sided, and p-values < 0.05 were considered statistically significant. Analyses were performed using SPSS 25.0 (IBM Corp., Chicago, IL).

RESULTS

As described above, 2 patients were switched from LMA to ETT during surgery, as they developed an air leak that suppressed the expiratory tidal volume to less than 4 mL/kg following pneumoperitoneum and change in the surgical posture. A total of 394 patients were finally analysed, including a group L comprising 170 patients and a group E comprising 224 patients. Patients' demographics and preoperative clinical features are described in Table 1. The mean anaesthesia time and duration of pneumoperitoneum were significantly prolonged in group E.

ETCO$_2$ and ventilator parameters during surgery are described in Table 2. ETCO$_2$ at times T2 and T3 were comparable between two groups. However, ETCO$_2$ at times T1 and T4 were higher in group L. The highest ETCO$_2$ during surgery was also higher in group L. The tidal volume (TV) at each time point except T1 showed no difference between two groups. The respiratory rate (RR) at the time of T1 was higher in group L, but remained unchanged at times T2, T3, and T4 between the two groups. All ETCO$_2$ values during surgery in group L were within the physiological range (below 45 mmHg) and RR remained below 19 breaths per minute during surgery. PIP at each time point except for T4 showed no difference between the two groups. The proportion of patients showing a PIP > 25 mmHg did not differ between the two groups. The linear mixed model revealed no significant group and time interaction for PIP during surgery ($p = 0.070$).

The number of patients who underwent ABGA at 2 h after anaesthesia induction was 216, and the results are described in Table 3. $PaCO_2$ at 2 h after induction was higher in group L (40.5 vs. 38.5 mmHg, $p < 0.001$), whereas the pH and proportion of patients with $PaCO_2$ > 45 mmHg and pH at that time were comparable between the two groups. PFR at 2 h after induction was comparable between the two groups. There was no significant difference in the proportion of patients with PFR < 200 and PFR < 300 during surgery.

Table 4 shows the incidence of PPCs between the groups. We included 4 patients who were initially excluded (2 patients whose LMA was switched to ETT during surgery and 2 patients with failed LMA insertion) in group L for comparison of PPCs. PPC occurred in 87 (21.9%) patients, with no difference between the two groups. Pulmonary aspiration did not occur. Pleural effusion and atelectasis occurred in 57 (14.3%) and 42 (10.5%) patients, respectively, and did not differ between the two groups. Respiratory infection occurred in 1 patient in group L. This patient had a history of pneumonia involving the right lower lobe two weeks before surgery, and pneumonia recurred 5 days after surgery.

DISCUSSION

Our results demonstrate that PLMA ensures adequate intraoperative gas exchange in patients undergoing LLR. Although a few intraoperative variables of ventilation differed between the two groups, the values were within the physiological range and the pH and PFR did not differ 2 h after induction. In addition, no statistically significant differences in $ETCO_2$, RR and PIP were found between the groups at most time points. For the time points where there were statistically significant differences, the difference is small and may be not clinically significant (Table 2). Increased intraabdominal pressure during laparoscopic surgery leads to early closure of small airways, and results in inadequate ventilation and oxygenation. Our results showed that adequate ventilation and oxygenation were maintained in patients with LMA even during pneumoperitoneum. Taheri et al reported a retrospective study of LMA used in major ear surgery involving 2,000 patients with a mean surgical time of about 200 min. Hemodynamic instability during surgery was not related to the duration of the surgery, and no gastric distension was observed in any patient.(15) However, their study was observational and did not compare LMA and ETT. The LMA used in the study was not second-generation and no variables related to intraoperative gas exchange were investigated. Although a few case reports(16,17) and one retrospective study(18) described the prolonged use of second-generation LMA, our report is the first of its kind suggesting that intraoperative gas exchange may be effective even with LMA in prolonged laparoscopic abdominal surgery.

The initial model of LMA and CLMA shows a temporal variation associated with the increased risk of inadequate ventilation due to structural limitations.(4,5) Therefore, CLMA is considered safe for only short and simple operations, and anaesthesiologists appear to be reluctant to use CLMA in prolonged surgery.(5,19) However, the LMA has evolved since its first development in 1981.(6,7) Second-generation LMA is specifically designed to overcome the disadvantages of CLMA.(6,7) Several studies have shown that the second-generation LMA enhances the sealing capacity, which might be key when used for a prolonged period.(13,20,21) Additionally, incorporating a gastric drainage tube with the second-generation LMA minimizes the likelihood of gastric insufflation. With these structural improvements, PLMA ensured adequate intraoperative gas exchange even in prolonged laparoscopic abdominal surgery in the current study.

LMA is faster and easier to insert than ETT, and is used as an alternative to ETT under conditions where tracheal intubation is difficult.(2,3,22) However, when ETT insertion is difficult during prolonged surgery, most clinicians are not clear whether ventilation and oxygenation can be safely maintained with LMA until the end of the surgery. Based on our results, a switch from the second generation LMA to ETT during prolonged laparoscopic surgery is not necessary for patients who had the LMA placed due to difficulties with intubation.

Pulmonary aspiration is one of the major concerns associated with LMA use. Even small amounts of pulmonary aspiration increase the risk of pneumonia or respiratory failure.(23) However, previous reports demonstrated that LMA with accurate positioning is not associated with increased risk of pulmonary aspiration.(2,24,25) Our study revealed no difference in PPC between the two groups, suggesting the absence of clinically significant micro-aspiration with PLMA. Nonetheless, it is unclear whether PLMA use is associated with an increased risk of pulmonary aspiration in the current study due to the small sample size. A very large sample size is required to demonstrate the difference in pulmonary aspiration under PLMA.(7)

This study has several limitations. First, as a retrospective study, we could not exclude the possibility of bias due to unmeasured or unmeasurable variables. For instance, we did not measure values that represent air leakage such as oropharyngeal leak pressure,(26) leak fraction,(27) or cuff pressure.(28) Additionally, a possible selection bias may exist due to differences in the duration of surgery between the two groups. We also could not compare the pharyngo-laryngeal complications such as sore throat and hoarseness. Second, although no symptoms or signs of aspiration were detected in group L, the small sample size prevented estimation of the risk of pulmonary aspiration.(7) Third, since LMA insertion was performed only by a single anaesthesiologist, it may be difficult to generalise to all physicians. Fourth, a significant difference was found in the duration of anaesthesia and pneumoperitoneum between the two groups, which may have influenced the outcome of PIP. If there was no difference in duration, there might be a possibility that the PIP was not different between two groups at the end of surgery. Fifth, the proportion of patients who underwent ABGA varied between the two groups. To overcome these limitations, well-controlled clinical trials are needed in the future. Finally, since we used only a single model of second-generation LMA, our results may not be generalised to other second-generation LMAs.

We conclude that during LLR, properly positioned PLMA ensures adequate intraoperative gas exchange compared with ETT. During prolonged laparoscopic abdominal surgery, the second-generation LMA may be an appropriate alternative to ETT.

REFERENCES

1. Yu SH, Beirne OR. Laryngeal mask airways have a lower risk of airway complications compared with endotracheal intubation: a systematic review. J Oral Maxillofac Surg 2010; 68:2359-76.
2. Cook TM, Lee G, Nolan JP. The ProSeal laryngeal mask airway: a review of the literature. Can J Anaesth 2005; 52:739-60.
3. Goldmann K, Hechtfischer C, Malik A, Kussin A, Freisburger C. Use of ProSeal laryngeal mask airway in 2114 adult patients: a prospective study. Anesth Analg 2008; 107:1856-61.
4. Ramachandran SK, Mathis MR, Tremper KK, Shanks AM, Kheterpal S. Predictors and clinical outcomes from failed Laryngeal Mask Airway Unique$^{\text{TM}}$: a study of 15,795 patients. Anesthesiology 2012; 116:1217-26.
5. Asai T. Complications with supraglottic airways: something to worry about or much ado about nothing? Anesthesiology 2012; 116:1183-5.
6. Timmermann A, Bergner UA, Russo SG. Laryngeal mask airway indications: new frontiers for second-generation supraglottic airways. Curr Opin Anaesthesiol 2015;

28:717-26.

7. Cook TM, Kelly FE. Time to abandon the 'vintage' laryngeal mask airway and adopt second-generation supraglottic airway devices as first choice. Br J Anaesth 2015; 115:497-9.
8. Maltby JR, Beriault MT, Watson NC, Liepert D, Fick GH. The LMA-ProSeal is an effective alternative to tracheal intubation for laparoscopic cholecystectomy. Can J Anaesth 2002; 49:857-62.
9. Kang SH, Park M. Comparison of early postoperative recovery between laryngeal mask airway and endotracheal tube in laparoscopic cholecystectomy: a randomized trial. Medicine (Baltimore) 2019; 98:e16022.
10. Canet J, Gallart L, Gomar C, et al. Prediction of postoperative pulmonary complications in a population-based surgical cohort. Anesthesiology 2010; 113:1338-50.
11. Marik PE. Aspiration pneumonitis and aspiration pneumonia. N Engl J Med 2001; 344:665-71.
12. American Society of Anesthesiologists. Standards for basic anesthetic monitoring. 2015. Available at: https://www.asahq.org/standards-and-guidelines/standards-for-basic-anesthetic-monitoring Accessed October 6, 2021.
13. Lu PP, Brimacombe J, Yang C, Shyr M. ProSeal versus the Classic laryngeal mask airway for positive pressure ventilation during laparoscopic cholecystectomy. Br J Anaesth 2002; 88:824-7.
14. Ozdamar D, Güvenç BH, Toker K, Solak M, Ekingen G. Comparison of the effect of LMA and ETT on ventilation and intragastric pressure in pediatric laparoscopic procedures. Minerva Anestesiol 2010; 76:592-9.
15. Taheri A, Hajimohamadi F, Soltanghoraee H, Moin A. Complications of using laryngeal mask airway during anaesthesia in patients undergoing major ear surgery. Acta

Otorhinolaryngol Ital 2009; 29:151-5.

16. Kammah M, Añez C. Prolonged use of the LMA Supreme^{TM}. Can J Anaesth 2013; 60:411-2.
17. Braude D, Southard A, Bajema T, Sims E, Martinez J. Rapid sequence airway using the LMA-Supreme as a primary airway for 9 h in a multi-system trauma patient. Resuscitation 2010; 81:1217.
18. Park S, Kim GS, Choi DH, et al. Comparison of pulmonary gas exchange during kidney transplantation: second-generation laryngeal mask airway vs endotracheal tube. Transplant Proc 2020; 52:1695-9.
19. Weiler N, Latorre F, Eberle B, Goedecke R, Heinrichs W. Respiratory mechanics, gastric insufflation pressure, and air leakage of the laryngeal mask airway. Anesth Analg 1997; 84:1025-8.
20. Keller C, Brimacombe J. Mucosal pressure and oropharyngeal leak pressure with the ProSeal versus laryngeal mask airway in anaesthetized paralysed patients. Br J Anaesth 2000; 85:262-6.
21. Micaglio M, Bonato R, De Nardin M, et al. Prospective, randomized comparison of ProSeal and Classic laryngeal mask airways in anaesthetized neonates and infants. Br J Anaesth 2009; 103:263-7.
22. Benger JR, Kirby K, Black S, et al. Effect of a strategy of a supraglottic airway device vs tracheal intubation during out-of-hospital cardiac arrest on functional outcome: the AIRWAYS-2 randomized clinical trial. JAMA 2018; 320:779-91.
23. Conces DJ Jr. Bacterial pneumonia in immunocompromised patients. J Thorac Imaging 1998; 13:261-70.
24. Brimacombe JR, Berry A. The incidence of aspiration associated with the laryngeal mask airway: a meta-analysis of published literature. J Clin Anesth 1995; 7:297-305.

25. Syeed SK. Risk of pulmonary aspiration with laryngeal mask airway and tracheal tube during positive pressure ventilation. Anaesthesia 2010; 65:532-3; author reply 533.

26. Keller C, Brimacombe JR, Keller K, Morris R. Comparison of four methods for assessing airway sealing pressure with the laryngeal mask airway in adult patients. Br J Anaesth 1999; 82:286-7.

27. Carron M, Veronese S, Gomiero W, et al. Hemodynamic and hormonal stress responses to endotracheal tube and ProSeal Laryngeal Mask Airway^{TM} for laparoscopic gastric banding. Anesthesiology 2012; 117:309-20.

28. Bick E, Bailes I, Patel A, Brain AI. Fewer sore throats and a better seal: why routine manometry for laryngeal mask airways must become the standard of care. Anaesthesia 2014; 69:1304-8.

Table 1. Demographics and preoperative clinical features

	Group L (n = 170)	Group E (n = 224)	*p* -value
Male	131 (77.1%)	153 (68.3%)	0.055
Age (years)	58 (46-66)	58 (48-66)	0.516
Height (cm)	165 (8.2)	164 (8.4)	0.211
BMI (kg/m^2)	24.8 (3.4)	24.5 (3.1)	0.410
Hypertension	41 (24.1%)	48 (21.4%)	0.527
Diabetes mellitus	61 (35.9%)	66 (29.5%)	0.177
Hemoglobin (g/dl)	14.2 (1.5)	14.0 (1.6)	0.160
Albumin (g/dl)	4.5 (0.4)	4.4 (0.4)	0.017
Anesthesia time (minutes)	223 (69)	290 (102)	<0.001
Pneumoperitoneum time (minutes)	139 (60)	188 (93)	<0.001
Infused crystalloid solution (ml/kg/hour)	4.7 (3.8-5.8)	4.7 (4.1-5.5)	0.761

Data are presented as mean (standard deviation) or median (interquartile range) or frequency (percent). Group L, laryngeal mask airway; Group E, endotracheal tube; BMI, body mass index.

Table 2. $ETCO_2$ and ventilator parameters during surgery

	Group L (*n* = 170)	Group E (*n* = 224)	*p* -value
$ETCO_2$ (mmHg)			
T1 (range) (IQR)	36 (29-41) (35-37)	35 (30-41) (34-37)	<0.001
T2 (range) (IQR)	38 (31-43) (36-39)	38 (30-47) (36-39)	0.822
T3 (range) (IQR)	38 (32-45) (36-40)	37 (30-44) (36-39)	0.149
T4 (range) (IQR)	38 (31-42) (36-40)	37 (30-44) (35-38)	<0.001
Highest $ETCO_2$ (mmHg)	40 (38-41)	39 (38-40)	0.002
Tidal volume (ml)			
T1 (range) (IQR)	457 (280-624) (406-502)	430 (249-578) (371-481)	<0.001
T2 (range) (IQR)	444 (256-638) (388-487)	432 (250-656) (371-477)	0.190
T3 (range) (IQR)	446 (259-666) (404-499)	437 (257-644) (383-484)	0.086
T4 (range) (IQR)	447 (252-588) (403-488)	439 (247-602) (388-481)	0.119
Respiratory rate (breaths/minute)			
T1 (range) (IQR)	10 (6-13) (8-10)	9 (5-13) (8-10)	<0.001
T2 (range) (IQR)	10 (7-19) (9-12)	10 (7-15) (9-12)	0.829
T3 (range) (IQR)	12 (8-16) (11-13)	12 (8-22) (10-13)	0.279
T4 (range) (IQR)	11 (6-16) (9-12)	10 (6-17) (10-12)	0.672
Peak inspiratory pressure (mmHg)			
T1 (range) (IQR)	16 (10-24) (15-17)	16 (9-22) (15-17)	0.742

T2 (range) (IQR)	21 (16-28) (20-23)	21 (15-28) (20-23)	0.859
T3 (range) (IQR)	22 (16-27) (21-23)	22 (16-30) (20-23)	0.672
T4 (range) (IQR)	17 (13-26) (16-19)	18 (12-26) (17-19)	<0.001
Peak inspiratory pressure > 25 (mmHg)	25 (14.7%)	43 (19.2%)	0.335

Data are presented as median (range) (interquartile range) or frequency (percent). Group L, laryngeal mask airway; Group E, endotracheal tube; $ETCO_2$, end-tidal pressure of carbon dioxide; IQR, interquartile range; $ETCO_2$, end-tidal pressure of carbon dioxide; T1, after induction of anesthesia; T2, after initiation of pneumoperitoneum; T3, before end of pneumoperitoneum; T4, end of surgery.

Table 3. Intraoperative arterial blood gas analysis.

	Group L (*n* = 109)	Group E (*n* = 107)	*p* -value
$PaCO_2$ (mmHg)			
2hours after induction (range) (IQR)	40.5 (30.9-56.3) (38.2-44.2)	38.5 (30.4-56.7) (36.3-41.1)	<0.001
PaCO2 > 45 (mmHg)	25 (22.9%)	16 (15.0%)	0.166
pH			
2hours after induction (range) (IQR)	7.36 (7.25-7.45) (7.33-7.39)	7.38 (7.24-7.46) (7.34-7.40)	0.090
PFR			
2hours after induction (range) (IQR)	542 (188-799) (438-610)	551 (288-769) (465-616)	0.215
PFR < 300	3 (2.8%)	4 (3.7%)	0.145
PFR < 200	1 (0.9%)	0	0.201

Data are presented as median (range) (interquartile range) or frequency (percent). Group L, laryngeal mask airway; Group E, endotracheal tube; IQR, interquartile range; $PaCO_2$, arterial partial pressure of carbon dioxide; PFR, arterial partial pressure of oxygen/fractional inspired oxygen.

Table 4. Postoperative pulmonary complications

	Group L (*n* = 174)*	Group E (*n* = 224)	*p* - value
At least 1 complication	37 (21.3%)	50 (22.3%)	0.770
Pulmonary aspiration	0	0	
Respiratory infection	1 (0.6%)	0	0.437
Pleural effusion	20 (11.5%)	37 (16.5%)	0.156
Atelectasis	20 (11.5%)	22 (9.8%)	0.590

Data are presented as frequency (percent). Group L, laryngeal mask airway; Group E, endotracheal tube.

*Four patients who were initially excluded (2 patients whose LMA was switched to ETT during surgery and 2 patients with failed LMA insertion) were included in group L.