ORIGINAL ARTICLE

Influence of endotracheal tube and laryngeal mask airway for general anesthesia on perioperative adverse events in patients undergoing laparoscopic hysterectomy: A propensity score-matched analysis

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Background: To compare perioperative adverse events between general anesthesia with endotracheal tube (ETT) and general anesthesia with laryngeal mask airway (LMA) in patients undergoing laparoscopic hysterectomy. **Materials and Methods:** This was a large sample retrospective, propensity score-matched (PSM) study. We collected the data of 6739 female patients who underwent laparoscopic hysterectomy between January 2016 and June 2021 in our hospital, China. Patients were divided into two groups (ETT group and LMA group) according to different airway management modes. Data on all perioperative adverse events were collected. PSM analysis was performed to control confounding factors and differences in baseline values between the two groups. Finally, 4150 female patients were recruited after PSM. **Results:** The total number of patients taking intraoperative vasoactive drugs during surgery was higher in the ETT group than in the LMA group ($P = 0.04$). The LMA group had a higher incidence of vomiting (51 [2.46%]) and somnolence (165 [7.95]) in the postanesthesia care unit (PACU) than the ETT group (71 [3.42%] and 102 [4.92%], respectively) ($P = 0.02$ and $P < 0.001$). Hypothermia was significantly higher in the LMA group (183 [10.36%]) than in the ETT group (173 [8.34%]) in the PACU ($P = 0.03$). The number of patients with sore throat was significantly higher in the ETT group (434 [20.02%]) than in the LMA group (299 [14.41%]) in the ward ($P < 0.001$). Other variables such as hypoxemia, moderate to severe pain, abdominal distension, diarrhea, sleep disorders, wound bleeding, and skin itch were not significantly different between the two groups ($P > 0.05$). **Conclusion:** The ETT group had more incidences of vomiting, sore throat, and cough complications and needed more drug treatment than the LMA group. LMA is a better airway management mode and LMA general anesthesia can be safely used in patients undergoing laparoscopic nonemergency hysterectomy.

Key words: Adverse events, endotracheal, general anesthesia, hysterectomy, laryngeal mask airway

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INTRODUCTION

Hysterectomy is a common treatment for benign and malignant uterine neoplasms. According to studies, the probability of undergoing hysterectomy is as high as 16%.[1] Hysterectomy accounts for the third largest number of gynecological operations in China. Compared to traditional abdominal hysterectomy, laparoscopic hysterectomy is associated with smaller abdominal incision, fewer postoperative complications, shorter hospital stays, faster recovery, and higher patient acceptance.[2]

Patients who undergo laparoscopic hysterectomy under general anesthesia require mechanical ventilation.

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However, airway management during surgery is complex because of the Trendelenburg position and carbon dioxide pneumoperitoneum. The endotracheal tube (ETT) can guarantee airway safety during laparoscopic hysterectomy. However, ETT can lead to several adverse events, such as arrhythmia, low blood oxygen concentrations, minor bleeding, pulmonary infection, and gastric distension with regurgitation.[3]

A laryngeal mask airway (LMA) is a small mask with an inflatable cuff attached to a silicone airway tube.[4] The LMA is inserted orally using anesthesiologist's index finger and guided along the hard palate without a laryngoscope or other instruments. LMA insertion is easy to perform without a laryngoscope and there is no contact with the tracheal mucosa. LMA has many advantages over ETT, such as greater hemodynamic and respiratory stability, less need for anesthetics, and fewer perioperative adverse events.[3,5,6] However, aspiration of gastric contents and air introduction into the stomach may be common when LMA is used.[7] LMA use is limited because of several procedure-related contraindications, such as certain anatomical findings, obesity, or lack of anesthesiologist experience.[8] The risks of using LMA in laparoscopic hysterectomy are highly debatable by anesthesiologists. Hence, this study compared all perioperative adverse events between general anesthesia with ETT and LMA in patients undergoing laparoscopic hysterectomy.

METHODS

Protocol

The study protocol was approved by the Clinical Research Ethics Committee of our hospital (protocol no: 2017/167; date: August 31, 2017) and registered in the Chinese Clinical Trial Registry (http://www.chictr.org.cn) with the identifier ChiCTR-ROC-17013036.

Study design

This was a single-center, large sample retrospective, propensity score-matched (PSM) study. A total of 6739 patients were investigated for eligibility. However, there were significant differences in patient characteristics such as the duration of surgery, duration of anesthesia, date of surgery, cumulative working hours of anesthesiologists, hypokalemia, intraoperative adjuvant analgesics, and patient-controlled analgesia (PCA) between the two groups ($P < 0.05$) [Table 1]. The use of propensity scores can compensate for the lack of randomness in intervention trials.[9] Hence, PSM analysis was performed to ensure that baseline characteristics between the two groups in the study were similar. The purpose of PSM was to control confounding factors and differences between the baseline values.

Propensity score-matched process

We used PSM analysis with logistic regression model using the psmatch2 command package in Stata 15. Logistic regression analysis was conducted to calculate the propensity scores. Ten variables that could have affected the perioperative adverse events were analyzed: Age, body mass index (BMI), anemia, hypokalemia, surgery duration, duration of anesthesia, date of surgery, intraoperative adjuvant analgesics, cumulative working hours of anesthesiologists, and postoperative use of PCA. PSM pairs were created at a 1:1 ratio based on the nearest neighbor matching algorithm with a 0.001-caliper distance without replacements. When the standardized mean difference was <10%, the balance of the baseline between the two groups was considered acceptable. Unpaired cases were excluded from the analysis.

Study participants

Data were collected from all patients scheduled to undergo laparoscopic hysterectomy under general anesthesia with an American Society of Anesthesiologists (ASA) physical status I-II between January 2016 and June 2021. The need for patient consent was waived because this was a retrospective study and anonymity was secured. Patient records were obtained from the electronic database of the hospital, including medical, anesthesia and analgesia, nursing, and postanesthesia care unit (PACU) records.

The exclusion criteria were as follows: Known risk factors for gastric aspiration, malignant tumor, underwent another surgery, BMI ≥30 kg/m^2, trachea compression and airway softening, unsuccessful LMA insertion, and incomplete data.[8,10]

We retrospectively reviewed the data of 6739 patients who underwent elective laparoscopic hysterectomy in our hospital between January 2016 and June 2021. Patients were divided into two groups: General anesthesia with ETT (ETT group) and general anesthesia with LMA (LMA group).

Perioperative management

None of the patients who underwent laparoscopic hysterectomy had received premedication. The patients were monitored using electrocardiography, pulse oximetry, noninvasive blood pressure, end-tidal CO_2 pressure, and bispectral index (BIS) after arrival at the operating room. Propofol or etomidate, muscle relaxants, and sufentanil were used for anesthesia induction.

An LMA or ETT was used to manage the airway. In the ETT group, cuffed ETTs with internal diameters of 7 mm were inserted. In the LMA group, a flexible-reinforced LMA (LMA Supreme, Zhejiang Shuguang Technology Co., Ltd., China) was used according to the patient's

Table 1: Patient characteristics for the total and propensity-matched cohorts

Variables	Total cohort			Matched cohort		
	LMA (*n*=2374)	ETT (*n*=4365)	*P*	LMA (*n*=2075)	ETT (*n*=2075)	*P*
Age (years)	51.30 (7.22)	51.30 (7.42)	1.00	51.37 (7.28)	51.31 (7.44)	0.82
BMI (kg/m^2)	23.44 (2.50)	23.49 (2.66)	0.46	23.43 (2.57)	23.41 (2.56)	0.78
Duration of anesthesia	117.40 (38.81)	124.97 (46.46)	<0.001	119.59 (39.53)	119.33 (38.13)	0.83
Duration of surgery	92.86 (37.31)	97.90 (39.20)	<0.001	94.46 (38.25)	94.23 (35.88)	0.85
Cumulative working hours	328.99 (146.61)	320.12 (145.02)	0.017	324.22 (145.68)	322.85 (145.86)	0.76
Year of surgery						
2016	315 (13.3)	583 (13.4)	<0.001	304 (14.7)	289 (13.9)	0.68
2017	207 (8.7)	858 (19.7)		207 (10.0)	195 (9.4)	
2018	235 (9.9)	931 (21.3)		235 (11.3)	266 (12.8)	
2019	735 (31.0)	783 (17.9)		560 (27.0)	575 (27.7)	
2020	534 (22.5)	817 (18.7)		487 (23.5)	471 (22.7)	
2021	348 (14.7)	393 (9.0)		282 (13.6)	279 (13.4)	
Intraoperative adjuvant analgesics	823 (34.7)	993 (22.7)	<0.001	595 (28.7)	626 (30.2)	0.29
PCA	1118 (47.1)	1881 (43.1)	0.002	972 (46.8)	976 (47.0)	0.90
Anemia	134 (5.6)	211 (4.8)	0.15	114 (5.5)	115 (5.5)	0.95
Hypokalemia	21 (0.9)	117 (2.7)	<0.001	21 (1.0)	31 (1.5)	0.16

Data are presented as *n* (%) or mean (SD). Resulted from Chi-square test or independent sample *t*-test. BMI=Body mass index; PCA=Patient controlled analgesia; LMA=Laryngeal mask airway; ETT=Endotracheal tube; SD=Standard deviation

weight. Propofol, remifentanil, and sevoflurane were all administered continuously to maintain BIS values of 40–60.

We administered nitroglycerin or urapidil when systolic blood pressure increased to >160 mmHg or 30% higher than baseline; when systolic blood pressure dropped to <80 mmHg, noradrenaline or ephedrine was administered. Esmolol was administered when the heart rate increased to >120 beats/min; when the heart rate decreased to <45 beats/min, atropine was administered. All surgeries were performed by experienced surgeons. The patients were extubated on the operating table.

Patients who experienced moderate or severe pain were treated with intravenous injection of 2 mg morphine in the PACU, and pain level was assessed every 10 min. If the numeric rating scale was >3, 2 mg morphine was administered again until the pain score was ≤3. Patients who experienced moderate or severe pain were treated with intravenous injection of 40 mg parecoxib in the ward, and pain level was assessed after 30 min. If the numeric rating scale was >3, 50 mg pethidine was administered.

Data collection and outcome measurements

The main outcome of this study was perioperative adverse events. Electronic medical records were reviewed by two researchers. We recorded medical histories, perioperative characteristics, postoperative outcomes, complications, and mortality. The following data were collected: Age, BMI, ASA classification, preoperative complications, surgery duration, duration of anesthesia, date of surgery, intraoperative adjuvant analgesics, cumulative working hours of anesthesiologists, postoperative use of PCA, and perioperative adverse events.

Perioperative adverse events included comorbidities of the cardiovascular and cerebrovascular systems, respiratory system, and nervous system. Nausea, vomiting, cough, hoarseness, dysphonia, and sore throat were assessed in the PACU. Sore throat, cough, nausea and vomiting, moderate-to-severe pain, abdominal distension, diarrhea, sleep disorders, wound bleeding, and skin itch were collected in the ward.

Pulse oxygen saturation <90% or arterial oxygen tension <60 mmHg was defined as hypoxemia. Hypothermia was defined as a body temperature <36°C.

Statistical analysis

The Kolmogorov–Smirnov test was used to verify the normal distribution of all data. Stata 15 SE (StataCorp, Texas, USA) statistical software was used for the analyses.[11,12] Continuous variables are presented as mean (standard deviation), whereas categorical variables are expressed as frequencies (percentages). The independent samples *t*-test and Chi-square test were used to determine statistically significant differences in continuous data and categorical variables, respectively. Considering the possibility of a bias caused by confounding factors and differences between the baseline values of the two groups, PSM was performed. In all analyses, a $P < 0.05$ was considered to indicate statistical significance.

RESULTS

A total of 6739 patients (LMA group, $n = 2374$; ETT group, $n = 4365$) were investigated for eligibility. After PSM, we recruited 4150 female patients (2075 LMA, 2075 ETT) who underwent laparoscopic hysterectomy under general

anesthesia. An acceptable matching balance was achieved in the matched cohort. All standardized mean differences of variables in this study were <10%.

The perioperative baseline data for this study are presented in Table 1. PSM was performed so that there was no difference in baseline values between the two groups. Patient characteristics were similar between the groups after PSM. The baseline mean age in the LMA group was 51.37 ± 7.28 years and that in the ETT group was 51.31 ± 7.44 years in the matched cohort data (P = 0.82). BMI was 23.43 ± 2.57 and 23.41 ± 2.56 kg/m^2 in the LMA and ETT groups, respectively (P = 0.78). The median surgical time (LMA 94.46 min vs. ETT 94.23 min) and the median anesthesia time (LMA 119.59 min vs. ETT 119.33 min) were not significantly different between the two groups.

There was no significant difference in the drugs used to raise or lower blood pressure and increase or decrease heart rate during surgery between the groups. However, the total number of patients taking intraoperative vasoactive drugs was higher in the ETT group (P = 0.042). Intraoperative bleeding was >400 mL in five patients. One patient who underwent endotracheal intubation developed bronchospasm during intubation. One of the 15 patients who received blood transfusion had an allergic reaction after blood transfusion [Table 2].

The LMA group had a higher incidence of vomiting (51 [2.46%]) and somnolence (165 [7.95]) in the PACU than the ETT group (71 [3.42%] and 102 [4.92%], respectively) (P = 0.02 and P < 0.001). There were significant differences in hypothermia between the LMA and ETT groups (P = 0.025): 183 (10.36%) developed hypothermia in the LMA group, whereas only 173 of 2075 patients (8.34%) presented with hypothermia in the ETT group. Hypoxemia, moderate-to-severe pain, hoarseness, and treatment with vasoactive drugs were slightly lower in the LMA group, but the difference was not statistically significant (P > 0.05) [Table 3].

In the ETT group, 434 (20.92%) complained of sore throat, whereas 299 patients (14.41%) complained of sore throat in the LMA group. The number of patients with sore throat was significantly higher in the ETT group than in the LMA group (P < 0.001). The incidence of cough was markedly lower in the LMA group than in the ETT group (P < 0.001). There was no difference in postoperative nausea and vomiting (PONV), moderate-to-severe pain, abdominal distension, diarrhea, sleep disorders, wound bleeding, or skin itching between the two groups in the ward (P > 0.05) [Table 4].

DISCUSSION

This retrospective study compared LMA with ETT for airway management during laparoscopic hysterectomy. We demonstrated that LMA yielded the advantage of early recovery in selected patients undergoing laparoscopic hysterectomy under general anesthesia. We found that the LMA maintained better intraoperative hemodynamic stability, reduced PONV in the PACU, and decreased postoperative sore throat and cough requiring medical intervention. To our knowledge, this is the first study to investigate the effects of LMA and ETT on all perioperative complications in patients undergoing laparoscopic hysterectomy. There is some doubt whether LMA can be used in patients undergoing laparoscopic surgery in clinical practice. Our study significantly confirmed that LMA reduces the incidence of perioperative complications; therefore, it is effective and safe to use LMA as an airway device in patients undergoing laparoscopic hysterectomy.

Previous studies have shown that endotracheal intubation is an invasive procedure that can stimulate the laryngopharynx and tracheal mucosa. Stimuli can lead to hypertension, tachycardia, and catecholamine release.[13,14] It may be harmful to patients with hypertension, glaucoma, cardiovascular disease, and cerebrovascular malformations. In our study, the differences in drugs used to raise blood pressure, lower blood pressure, increase heart rate, and reduce heart rate during surgery between the two groups were not statistically significant. However, the total number of patients taking intraoperative vasoactive drugs was higher in the ETT group (P = 0.042). Compared with

Table 2: Intraoperative adverse events in the two groups

Variables	LMA (n=2075)	ETT (n=2075)	P
Number of people taking drugs for raising blood pressure	366 (17.6)	411 (19.8)	0.07
Number of people taking drugs for lowering blood pressure	100 (4.8)	101 (4.9)	0.94
Number of people taking drugs for increasing heart rate	318 (15.3)	334 (16.1)	0.49
Number of people taking drugs for reducing heart rate	8 (0.4)	7 (0.4)	0.91
Number of people taking vasoactive drugs	674 (32.5)	735 (35.4)	0.04
Bronchospasm during intubation	0	1 (0.05)	0.31
Bleeding >400 mL	1 (0.05)	4 (0.19)	0.19
Blood transfusion	6 (0.29)	9 (0.43)	0.44

Data are presented as n (%). Resulted from Chi-square test. LMA=Laryngeal mask airway; ETT=Endotracheal tube

Table 3: Postoperative adverse events in postanesthesia care unit

Variables	LMA (*n*=2075)	ETT (*n*=2075)	*P*
Vomiting	51 (2.46)	71 (3.42)	0.024
Hypothermia	215 (10.36)	173 (8.34)	0.025
Hypoxemia	183 (8.82)	206 (9.93)	0.22
Somnolence	165 (7.95)	102 (4.92)	<0.001
Hoarseness	1 (0.05)	1 (0.05)	1.00
Moderate to severe pain	25 (1.21)	30 (1.45)	0.50
Treatments with vasoactive drugs	45 (2.2)	51 (2.5)	0.54

Data are presented as *n* (%). Resulted from Chi-square test. LMA=Laryngeal mask airway; ETT=Endotracheal tube

Table 4: Postoperative adverse events in the ward

Variables	LMA (*n*=2075)	ETT (*n*=2075)	*P*
Sore throat	299 (14.4)	434 (20.9)	<0.001
Cough	193 (9.3)	413 (19.9)	<0.001
Nausea and vomiting	266 (12.8)	241 (11.6)	0.24
Moderate to severe pain	689 (33.2)	740 (35.7)	0.10
Abdominal distension	577 (27.8)	544 (26.2)	0.25
Diarrhea	15 (0.7)	23 (1.1)	0.19
Sleep disorders	161 (7.8)	143 (6.9)	0.28
Wound bleeding	52 (2.5)	62 (3.0)	0.34
Skin itch	37 (1.8)	42 (2.0)	0.57

Data are presented as *n* (%). Resulted from Chi-square test. LMA=Laryngeal mask airway; ETT=Endotracheal tube

endotracheal intubation, LMA insertion can attenuate the cardiovascular response.

The Trendelenburg position is often used in laparoscopic hysterectomy. Previous studies have shown that carbon dioxide pneumoperitoneum during laparoscopic surgery can increase the abdominal volume, increase the intra-abdominal pressure, move the diaphragm upward, reduce the thoracic volume, increase the intra-thoracic pressure, and limit the thoracic expansion. When the patient is in the Trendelenburg position again, the patient will experience an imbalanced ventilation/blood flow ratio, decreased lung ventilation, and decreased tidal volume, which may easily lead to hypercapnia.[15] In addition, the Trendelenburg position can prevent reflux from entering the airway by mistake and avoid suffocation. In our study, hypercapnia was not significantly different between the two groups. In the LMA group, 166 (8%) patients had pneumoderma, whereas 172 (8.29%) patients experienced pneumoderma in the ETT group. There was no significant difference in hypercapnia between the two groups ($P = 0.78$). Only one ETT patient was sent to the intensive care unit because of tracheal spasms after the operation and failed tracheal extubation several times. LMA was not successfully inserted in 26 patients because of an air leak. However, ETT intubation failed in 14 patients because of a difficult airway; therefore, endotracheal intubation under the guidance of fiber-optic bronchoscopy was adopted. No patient had aspiration from regurgitated gastric contents. Therefore, LMA may be safe during general anesthesia in patients with hypertension, cardiovascular disease, or glaucoma undergoing laparoscopic hysterectomy, with considerably fewer cardiovascular complications.[10]

Postoperative sore throat is a common complication of general anesthesia. Postoperative sore throat is considered a relatively minor syndrome; however, it can decrease patient satisfaction and prolong hospital stay.[8] Therefore, more attention should be paid by the medical staff. Higgins *et al*. conducted a prospective study of 5264 patients following ambulatory surgery and found that 12.1% of patients had sore throat, and the ETT group had a slightly higher incidence of sore throat than the LMA group.[16] The upper airway is directly damaged when rigid materials are used. Laryngoscopy, tube size, sex, BMI, surgery type, and cuff pressure during endotracheal intubation can cause physical tension. Direct trauma to the airway and physical tension may lead to postoperative throat. Our study demonstrated that the incidence of postoperative sore throat in the LMA group was significantly lower than that in the ETT group.

PONV and cough can cause sympathetic nerve activation, bronchospasm, and desaturation. Previous studies have confirmed that LMA can decrease PONV during the 1st h in the PACU.[17] This finding is consistent with the results of our study. The incidence of vomiting in the PACU was significantly lower in the LMA group than in the ETT group ($P = 0.024$). The LMA cuff has a stronger stimulation to the pharynx than the ETT cuff stimulation to the trachea. LMA has been considered to improve the PONV threshold through a preemptive type of mechanism.[18] However, no difference was observed between the two groups in the incidence of PONV in the ward. A meta-analysis indicated that the probability of postoperative cough in patients undergoing general anesthesia with an LMA is lower than that that in patients with ETT.[19] Supporting those findings, our study showed that the incidence of postoperative cough was significantly lower in the LMA group than in the ETT group. Previous studies have found that patients with ETT are more likely to have swelling of the vocal cords and narrowing of the glottic apertures; however, this does not occur after surgery in patients with LMA.[17] The reason for postoperative cough may be the local mucosa, laryngeal edema, and vocal cord trauma caused by the ETT.

Hypothermia is more likely to occur during general anesthesia. General anesthesia may inhibit central thermoregulation and induce peripheral vasodilation. Anesthetic drugs, low temperature in the operating room, preoperative disinfection, intraoperative infusion, and peritoneal lavage can lead to hypothermia.[20] Our study confirmed that the incidence of hypothermia was not significantly different in

different months (P = 0.08). It may be because our hospital uses central air conditioning all year round to maintain an indoor temperature of 24°C–26°C. Hypothermia occurred more frequently in the LMA group than in the ETT group in the PACU (P = 0.025). A possible explanation of the higher incidence of hypothermia in the LMA group is that the patients' face and neck were fully exposed to facilitate the observation and management of the airway. The proportion of patients with somnolence in the LMA group was higher than that in the PACU group (P < 0.001). Previous studies have shown that the dose of anesthetics can be significantly reduced. In our study, the anesthetic drugs used in the two groups were roughly the same to ensure the depth of anesthesia during laparoscopic surgery.

Consistent with previous research results,[10] our study found that only one patient in the ETT group developed bronchospasm during intubation but none in the LMA group (no statistically significant difference between groups). LMA was not successfully inserted in 26 patients because of an air leak. However, ETT intubation failed because of a difficult airway; therefore, endotracheal intubation under fiber-optic bronchoscopy was adopted. No patient had aspiration from regurgitated gastric contents.

Strengths and weaknesses

Our study had some limitations. First, because of its retrospective nature, this study could not confirm the integrity of data such as airway pressure and lung compliance. A prospective, randomized controlled study may be undertaken in the future. Second, a previous study found that women recovered faster from general anesthesia than men, but their quality of recovery was worse than that of men.[21,22] Therefore, our study included only women. However, this study included 4150 patients undergoing laparoscopic hysterectomy. Therefore, the results will be beneficial in clinical practice.

CONCLUSION

The frequency of vasoactive drug use and incidence of vomiting, sore throat, and postoperative cough were higher in the LMA group than in the ETT group. The ETT group had more perioperative complications and needed more drug treatment than the LMA group. Hence, LMA is a better airway management mode and LMA general anesthesia can be safely used in patients undergoing laparoscopic nonemergency hysterectomy.

Acknowledgments

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Conflicts of interest

There are no conflicts of interest.

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