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Original Article

Effect of airway management method on hypothermia in patients undergoing laparoscopic gynecologic surgery: tracheal intubation, supreme laryngeal mask, and i-gel laryngeal mask

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Abstract: Objective: This study aimed to assess the association between different airway management methods and perioperative hypothermia in gynecologic laparoscopic surgery. Methods: This single-center prospective cohort observational study included patients who underwent gynecologic laparoscopic surgery between September 2022 and February 2023. A total of 531 patients scheduled for non-emergent surgery were recruited and randomly assigned to the tracheal intubation group (T group) (n = 153), supreme laryngeal mask group (L group) (n = 156), or i-gel laryngeal mask group (i group) (n = 151). Following anesthesia induction, the primary outcome was the incidence of intraoperative hypothermia at the end of surgery. Secondary outcomes included final core body temperature, incidence of nosebleeds, flushing and fluid administration, urine output, and other relevant parameters. Multivariate logistic regression analyses were conducted to identify risk factors associated with hypothermia. Results: The incidence of postoperative hypothermia in the L and i groups was significantly lower than of the T group ($P < 0.05$). At the end of surgery, the core body temperature in the T group was also lower than in the L and i groups ($P < 0.05$). Extubation and recovery times differed significantly among the three groups, with the T group showing longer durations compared to the two laryngeal mask groups ($P < 0.05$). During postoperative follow-up, the incidence of nasal bleeding in the T group was higher than of the other two groups ($P < 0.05$). No significant differences were observed in the incidence of other postoperative complications ($P > 0.05$). Conclusion: In patients undergoing gynecologic laparoscopic surgery, tracheal intubation is associated with a higher likelihood of perioperative hypothermia compared to laryngeal mask use.

Keywords: Anesthesia, perioperative inadvertent hypothermia, laparoscopic gynecologic surgery, tracheal intubation

Introduction

Maintaining body temperature is essential during laparoscopic gynecologic surgery. Factors such as abdominal cavity exposure, cold light sources, and the infusion of large volumes of cold fluids contribute to an increased risk of hypothermia. Hypothermia not only disrupts physiologic function and raises surgical risks but may also extend postoperative recovery time. A core body temperature drop below 36°C during the perioperative period, regardless of the cause, is classified as perioperative hypothermia (PIH), also referred to as unexpected hypothermia in this context. Currently, hypothermia is a frequent occurrence in surgical patients. Studies conducted both domestically and internationally report a wide range of intraoperative hypothermia incidence, estimated at approximately 7-90% [1-4]. Various factors, including a cold operating room environment, fluid temperature, surgical duration and type, and anesthesia management, contribute to PIH development [5-7]. PIH can decrease metabolic rate and cardiac output, prolong drug metabolism, elevate the risk of postoperative infection and shivering, delay surgical wound healing, and impair coagulation and immune function, and lead to increased hospital stays and medical costs [3, 6, 8-10].

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Laparoscopy has become a preferred approach for gynecologic surgery due to its advantages of minimal trauma and rapid postoperative recovery. However, factors such as insufflation of the abdominal cavity with cold CO_2 gas and the use of low-temperature flushing fluids contribute to a high incidence of postoperative chills, reported to range between 29.0% and 40.0% [4, 5, 11, 12]. As a result, reducing the occurrence of PIH remains a primary concern for clinical anesthesiologists. During inhalation, significant temperature fluctuations occur within the chest and lung airways. The upper respiratory tract plays a vital role in regulating the temperature and humidity of inhaled gases, with the nasopharynx being particularly important due to its extensive blood supply, glandular structures, and the large surface area of its convoluted nasal mucosa. This anatomic adaptation allows incoming air to be warmed and humidified, reaching nearly core body temperature and 100% relative humidity before it reaches the tracheal prominence [13-16]. Studies indicate that perioperative respiratory heat loss in patients under general anesthesia accounts for approximately 10-20% of total intraoperative energy loss. Tracheal intubation, the supreme laryngeal mask airway (LMA), and the i-gel laryngeal mask are three widely used ventilation devices in clinical practice. The structural differences between these devices result in varying levels of airflow heating, which may influence body temperature regulation. During general anesthesia in adults, a tracheal tube is typically inserted to a depth of approximately 22-24 cm, with the tube outlet positioned at the mid-trachea. This placement allows fresh air to enter directly without undergoing preheating, significantly impairing the airway's natural ability to regulate inhaled gas temperature and retain heat [17, 18]. In contrast, the laryngeal mask is a supraglottic ventilation device that, unlike tracheal intubation, helps preserve the upper respiratory tract's insulation effect [19, 20].

Airway management is a critical component of anesthesia care, playing a key role in maintaining stable patient temperature. Common airway devices, including tracheal intubation, the supreme laryngeal mask, and the i-gel laryngeal mask, are widely used in clinical practice to ensure airway patency and maintain anesthesia safety during surgery. However, their effect on body temperature in patients undergoing laparoscopic gynecologic surgery has been largely overlooked. Investigating how different airway management techniques influence hypothermia in laparoscopic gynecologic surgery may help refine airway management strategies, minimize fluctuations in body temperature, improve surgical safety, and improve patient comfort. This study aimed to evaluate the effects of three airway devices on core body temperature under identical conditions, providing clinical guidance for the management of intraoperative temperature in patients under general anesthesia.

Patients and methods

Patients

This prospective clinical trial was approved by the Institutional Review Board of Qilu Hospital of Shandong University and registered at chictr.org (ChiCTR2100046399). Written informed consent was obtained from all participants.

Inclusion criteria were as follows: patients classified as American Society of Anesthesiologists (ASA) class I to III, aged between 16 and 60 years, with a body mass index (BMI) ranging from 18.5 to 24.9, an expected surgical duration of more than one hour, and scheduled for laparoscopic gynecologic surgery under general anesthesia between September 2022 and February 2023. Exclusion criteria included: patients with upper respiratory tract pathology, limited mouth opening (< 3 cm) or a high risk of regurgitation and aspiration, fever (> 37.3°C) or tympanic membrane temperature < 36.0°C, thyroid-related or metabolic disorders, severe cardiovascular or cerebrovascular disease, uncontrolled diabetes mellitus, hepatic or renal insufficiency, psychiatric or neurological disorders, or an inability to effectively communicate their intentions. Patients enrolled in other clinical trials, those unwilling to participate, and those deemed ineligible based on clinical judgment were also excluded.

Randomization and blinding

Participants were randomly assigned using a computer-generated randomization table. A preoperative assessment was conducted the day before surgery by an anesthetist who was not involved in the study details. On the day of surgery, the attending anesthetist was informed

of the assigned ventilation device, and perioperative data were recorded accordingly. Postoperative follow-up was conducted by a researcher who was unaware of the group allocations. The data analyst was not involved in preoperative assessment, perioperative management, or postoperative follow-up. The researcher responsible for patient recruitment, as well as the patients and other healthcare team members, remained blinded to the group assignments.

Anesthesia, perioperative care and intervention

All patients received an intramuscular injection of atropine (0.01 mg/kg) 30 minutes before surgery. The operating room temperature was maintained at 23.0 ± 1.0°C, with a relative humidity of approximately 50%. To maintain warmth, all patients were covered with cotton blankets and placed on heating pads. Intravenous fluids and blood transfusions were administered following standard clinical protocols, with all fluids and flushes prewarmed to 37.0°C. Intraoperative monitoring (M8003A, Philips Medizin Systeme Boeblingen GmbH) included electrocardiography, pulse oximetry, mean arterial pressure (MAP), capnography, inhaled anesthetic concentration, bispectral index (BIS), nasopharyngeal temperature (MR-411, Shenzhen Mindray Bio-Medical Electronics Co., Ltd., China), peak airway pressure, and urine output. To reduce the risk of postoperative nausea and vomiting, glucocorticoids were administered following anesthesia induction, with dexamethasone (5-10 mg) or methylprednisolone (40 mg) given as needed.

General anesthesia was induced using midazolam (0.05 mg/kg), sufentanil (0.4-0.5 μg/kg), propofol (2-2.5 mg/kg) or etomidate (0.2 mg/kg), and rocuronium. Once the eyelash reflex disappeared, all patients received rocuronium (0.6 mg/kg), and tracheal intubation or laryngeal mask placement was performed approximately 80 seconds later. Patients in the T group underwent intubation with a 7.0# steel wire endotracheal tube (SJ-I-7.0, Zhejiang Sujia Bio-Medical Electronics Co., Ltd., China). Patients in the L group (175030/175040, Teleflex Medical Electronics Co., Ltd., Ireland) and I group (8203000/8204000, Intersurgical Ltd Electronics Co., Ltd., England) were fitted with a supreme or i-gel laryngeal mask, respectively, with size selection based on body weight. Patients weighing 30-50 kg received a 3.0# laryngeal mask, while those weighing 50-70 kg received a 4.0# mask. For minimal invasiveness and ease of operation, patient temperature was measured using an infrared tympanic thermometer before anesthesia induction and after surgery. A temperature probe was inserted into the nasal cavity to a depth of 9-10 cm immediately after anesthesia induction, and continuous temperature monitoring was recorded. Once temperature stabilization was achieved, the baseline temperature (T0) was recorded. Nasopharyngeal temperature was documented at the start of surgery (T1) and then at 20-minute intervals until the end of the procedure (TEND). Additionally, any related complications were recorded.

All patients underwent ultrasound-guided transversus abdominis plane (TAP) block. Anesthesia was maintained with inhaled sevoflurane (1.5%-2%), along with an infusion of isoproterenol, remifentanil, or sufentanil (by infusion or injection). The depth of anesthesia was controlled to keep the BIS between 40 and 60, while mean arterial pressure (MAP) fluctuations were maintained within 20% of baseline. Nonsteroidal anti-inflammatory drugs (NSAIDs) were administered unless contraindicated.

To prevent postoperative nausea and vomiting, ondansetron (8 mg) and dexamethasone (5 mg) were slowly infused intravenously 30 minutes before the completion of surgery. At the end of the procedure, the nasopharyngeal temperature probe was removed, and extubation time, awakening time, and the occurrence of adverse reactions, such as postoperative chills, were documented. Extubation was facilitated with flumazenil (0.5 mg), neostigmine (0.02 mg/kg), and atropine (0.01 mg/kg) before removal of the airway device. Patients were deemed ready to leave the operating room and return to the ward when they achieved a Steward score of 6.

Postoperatively, blood pressure (BP), electrocardiography (ECG), and pulse oximetry were monitored intermittently until the following morning, and once or twice daily thereafter until discharge for patients transferred to the general ward. Patient-controlled intravenous analgesia (PCIA) was initiated immediately after extubation, delivering sufentanil at a rate of

0.02 μg/kg/h with an additional 0.005 μg/kg bolus, followed by a 15-minute lockout period. The goal was to maintain a pain numeric rating scale score of ≤3. Adjunctive analgesics, typically flurbiprofen axetil (50 mg IV), were provided as needed. For patients who developed postoperative fever, antibiotics and glucocorticoids were administered when necessary. The incidence of nausea, vomiting, dizziness, epistaxis, sore throat, and tremors was recorded, along with the length of postoperative hospital stay.

Outcomes

The primary outcome was unanticipated intraoperative hypothermia, defined as a core temperature below 36°C at any point during the perioperative period. Temperature was continuously monitored using a nasopharyngeal temperature probe, with recordings taken every 20 minutes preoperatively, intraoperatively, and postoperatively.

Secondary outcomes included core temperature, temperature reduction, total flush volume, total fluid infusion, urine output, type of surgery, intraoperative anesthetic dose, hemodynamic changes, duration of anesthesia, duration of surgery, extubation time (measured from the end of surgery to removal of the tracheal tube or laryngeal mask), recovery time (measured from the end of surgery until the Steward score exceeded 6), incidence of postoperative shivering, prevalence of postoperative epistaxis, postoperative sufentanil consumption, pain intensity at 24 hours postoperatively, length of hospital stay, and other adverse events. Vital signs were recorded at the following time points: before anesthesia induction (T0), upon insertion of the ventilation device (T1), before surgical incision (T2), at pneumoperitoneum establishment (T3), at the end of surgery (T4), upon removal of the ventilation device (T5), and before the patient left the operating room (TEND). Pain intensity was assessed at rest and during movement using the NRS, an 11-point scale where 0 represents no pain and 10 represents the worst possible pain. A difference of at least 1 point was considered clinically meaningful.

Statistical analysis

Based on findings from our pilot study, intraoperative hypothermia was observed in 45% of patients undergoing tracheal intubation, 30% of those using a supreme laryngeal mask, and 28% of those with an i-gel laryngeal mask. Using the highest incidence rate for paired group comparisons, a total of 479 subjects were required to achieve 80% power at an alpha level of 0.05. Accounting for a 10% dropout rate, a minimum of 177 patients per group was needed, leading to a total planned recruitment of 531 patients.

For continuous quantitative data, normally distributed variables were expressed as mean ± standard deviation, and one-way ANOVA was used for multiple-group comparisons. When data did not follow a normal distribution, values were reported as medians (interquartile range), and intergroup comparisons were conducted using the rank-sum test. Categorical variables were presented as numbers (n) and percentages (%), with comparisons made using the chi-square test or Fisher's exact test as appropriate. For ordinal data, intergroup differences were analyzed using the rank-sum test. For binary outcomes such as core body temperature, generalized estimating equations (GEE) were applied for statistical analysis, with odds ratios (ORs) and 95% confidence intervals (CIs) calculated for between-group comparisons. The model was adjusted for confounding variables, including age, BMI, Mallampati grade, ASA classification, hypertension, diabetes mellitus, and coronary heart disease. For repeated measurements, such as body temperature, this study accounted for missing follow-up data by employing the generalized estimation equation (GEE) model using the geepack package in R. The correlation structure was set to "exchangeable", and the model included group, time, and group × time interaction terms while adjusting for potential confounders such as age, BMI, Mallampati grade, ASA classification, hypertension, diabetes mellitus, and coronary heart disease. Additionally, a line chart was generated to visualize the estimated mean values at different time points across the study groups.

Data analysis was conducted using R Programming Language (version 4.3.2). A multiple linear regression model was applied to determine the study's dependent variable and assess the independent variables that could influence it. The model assumed a linear relationship between the dependent and independent variables, and a linear model was con-

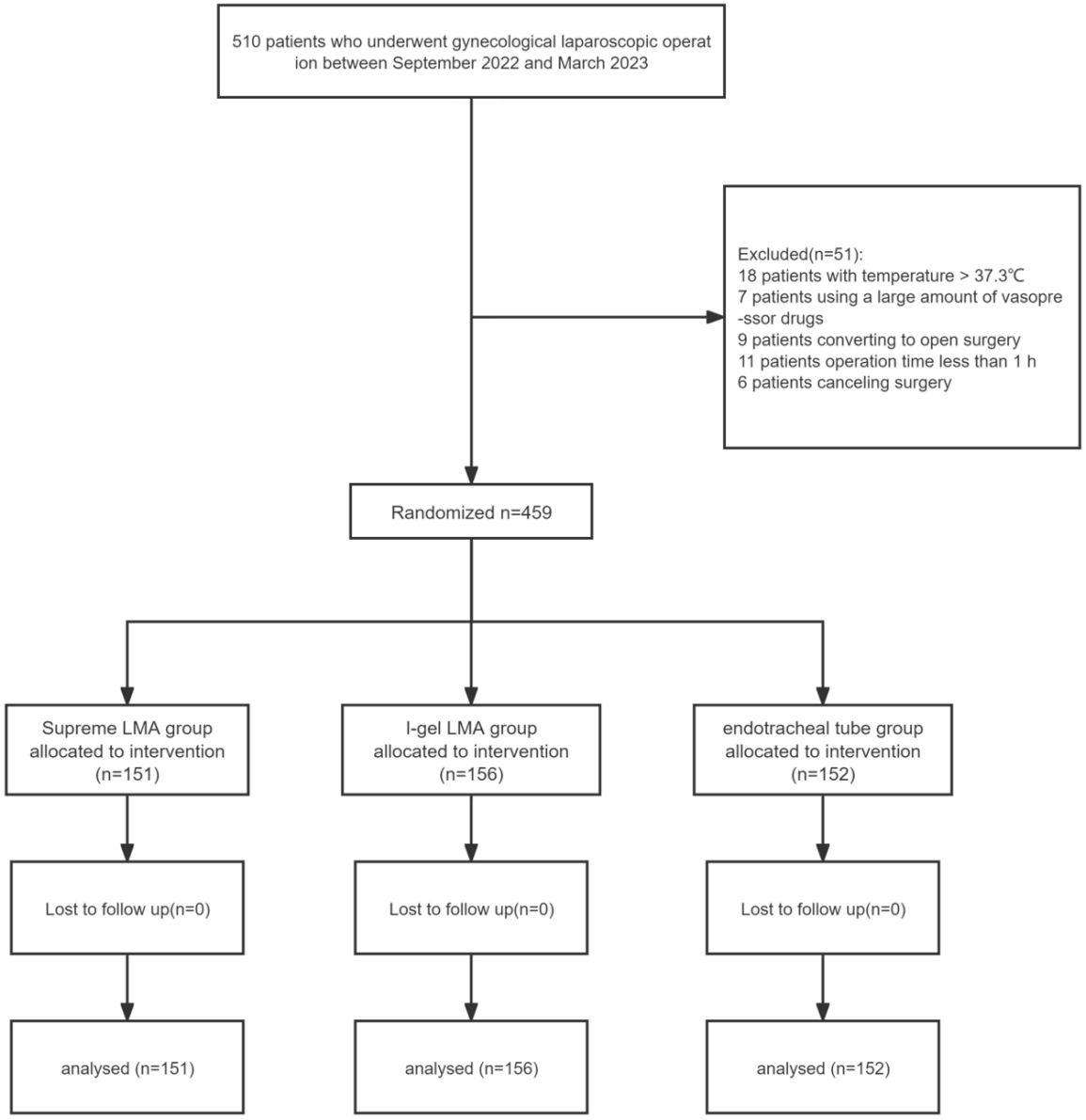

Figure 1. Flow chart.

structed accordingly. Model fitting was performed using the lm() function, with detailed results examined using the summary() function. Diagnostic checks were conducted to identify issues such as multicollinearity or heteroskedasticity, and necessary adjustments were made to address them. The fitted model was used for prediction and interpretation. No adjustments were made for multiple comparisons, as the study followed a registry protocol without a predefined analytical plan. The analyses were conducted post hoc, and the findings should be considered exploratory, serving as a foundation for future definitive studies.

Results

Baseline characteristics of study population

Figure 1 presents the flow diagram of patient enrollment in this study. A total of 510 patients scheduled for gynecologic laparoscopic surgery between September 2022 and February 2023 were recruited. Among them, 51 patients were excluded due to the following reasons: 18 had a preoperative temperature exceeding 37.3°C, 7 required high doses of vasopressor drugs, 9 underwent conversion to open surgery, 11 had an operative time of less than one hour, and 6

Table 1. Patient general demographic characteristics

	i group (n = 151)	L group (n = 156)	T group (n = 152)	*P value*
Age (yrs)	46.00 (38.00, 51.50)	44.00 (34.00, 52.00)	45.50 (36.00, 52.00)	0.713
BMI (kg/m^2)	24.44 (22.05, 27.16)	24.06 (21.48, 26.58)	23.78 (22.08, 25.90)	0.323
ASA, n (%)	-	-	-	0.814
I	27 (17.9)	34 (21.8)	34 (22.4)	-
II	115 (76.2)	111 (71.2)	110 (72.4)	-
III	9 (6)	11 (7.1)	8 (5.3)	-
Mallampati grade, n (%)	-	-	-	0.074
I	50 (33.1)	42 (26.9)	50 (32.9)	-
II	81 (53.6)	104 (66.7)	82 (53.9)	-
III	20 (13.2)	10 (6.4)	20 (13.2)	-
Preoperative comorbidities	-	-	-	-
Hypertension, n (%)	36 (23.8)	43 (27.6)	35 (23)	0.616
Diabetes mellitus, n (%)	35 (23.2)	38 (24.4)	35 (23)	0.955
Coronary heart disease, n (%)	15 (9.9)	18 (11.5)	15 (9.9)	0.863

Note: Data are expressed as mean ± SD, median (interquartile range) and percentage. BMI: body mass index; ASA: American society of anesthesiologists; i group: i-gel laryngeal mask group; L group: supreme laryngeal mask group; T group: tracheal intubation group. Differences were considered to be statistically significant when $P < 0.05$.

Table 2. Perioperative core temperature evolution

Operation time (min)	i group (n = 151)	L group (n = 156)	T group (n = 152)	*P* value		
				i group vs. L group	T group vs. i group	T group vs. L group
anesthesia induction	36.58 ± 0.05	36.58 ± 0.06	36.60 ± 0.07	0.971	0.547	0.478
0	36.56 ± 0.05	36.57 ± 0.06	36.58 ± 0.06	0.839	0.657	0.79
20	36.58 ± 0.05	36.57 ± 0.07	36.54 ± 0.07	0.843	0.289	0.331
40	36.50 ± 0.06	36.51 ± 0.07	36.44 ± 0.07	0.901	0.16	0.094
60	36.41 ± 0.06	36.42 ± 0.07	36.32 ± 0.07	0.810	0.08	0.032
80	36.32 ± 0.06	36.35 ± 0.07	36.24 ± 0.07	0.698	0.097	0.027
100	36.24 ± 0.06	36.27 ± 0.07	36.16 ± 0.07	0.653	0.202	0.063
120	36.17 ± 0.07	36.21 ± 0.08	36.12 ± 0.08	0.638	0.478	0.202
140	36.12 ± 0.07	36.26 ± 0.09	36.11 ± 0.08	0.153	0.833	0.078
160	36.09 ± 0.12	36.22 ± 0.10	36.09 ± 0.08	0.318	0.974	0.164
180	35.96 ± 0.25	36.14 ± 0.13	36.02 ± 0.09	0.489	0.802	0.345
Tend	36.28 ± 0.06	36.27 ± 0.07	36.13 ± 0.07	0.954	0.003	0.002

Note: Data are expressed as mean ± SD. Tend: temperature at the end of surgery; i group: i-gel laryngeal mask group; L group: supreme laryngeal mask group; T group: tracheal intubation group. Differences were considered to be statistically significant when $P < 0.05$.

canceled their surgery. Ultimately, 459 patients were randomly assigned to one of three groups: the tracheal intubation group (n = 152), the supreme LMA group (n = 156), or the i-gel LMA group (n = 151). Baseline characteristics were well balanced across the three groups, except for a difference in the Mallampati score, which was not considered clinically significant (**Table 1**).

Incidence of hypothermia and patient outcomes

The incidence of perioperative hypothermia varied among surgical patients depending on the airway management method used, as shown in **Table 2** ($P < 0.001$). Hypothermia occurred less frequently in the LMA groups (both supreme and i-gel) compared to the tra-

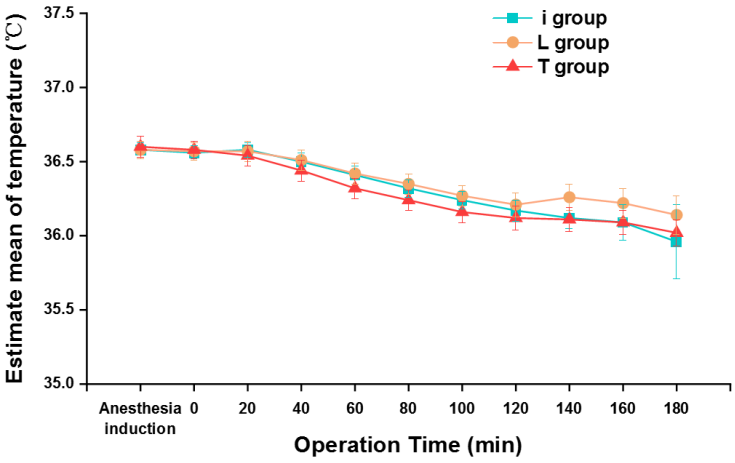

Figure 2. Mean perioperative temperature (°C) in each group.

cheal intubation group, with no significant difference between the two LMA groups (I vs. L: 21.19% vs. 21.15%, P = 0.916; I vs. T: 21.19% vs. 37.91%, P = 0.002*; L vs. T: 21.15% vs. 37.91%, P = 0.001*; **Table 2**). Following airway device placement, body temperature in all three groups showed a decreasing trend (**Figure 2**). By the end of surgery, core body temperature differed significantly among the groups, with patients in the tracheal intubation group exhibiting significantly lower temperatures compared to those in the LMA groups (I vs. T: 36.30°C (36.00, 36.60) vs. 36.10°C (35.80, 36.40), P < 0.001*; L vs. T: 36.30°C (36.00, 36.50) vs. 36.10°C (35.80, 36.40), P = 0.002*; **Table 2**).

Among the secondary outcomes, extubation and recovery times were longer in the tracheal intubation group compared to the two LMA groups (I vs. T: 5.00 (5.00, 9.00) vs. 7.00 (5.00, 10.00), P < 0.001*; L vs. T: 5.00 (5.00, 10.00) vs. 7.00 (5.00, 10.00), P = 0.019*; **Table 3**). Additionally, differences were observed among the groups regarding perioperative anesthetic drug use, including sufentanil, remifentanil, and sevoflurane consumption (**Table 3**). There were no significant differences among the groups in other intraoperative data. The incidence of immediate postoperative epistaxis and shivering also showed no statistical difference among the three groups. Trends in vital signs during surgery were visualized by line graphs (**Figure 3**), with specific numerical values provided in the appendix (Tables S1, S2, S3, S4, S5).

Postoperative evolution of patients

At 24 hours postoperatively, the incidence of nosebleeds was significantly higher in the tracheal intubation group compared to the supreme LMA group (L vs. T: 4.49% vs. 11.18%, P = 0.03*; **Table 3**). Additionally, pain scores during movement were higher in the tracheal intubation group than in the LMA group (L vs. T: 3.00 (2.00, 4.00) vs. 3.00 (3.00, 4.00), P = 0.019*; **Table 4**). The total volume of sufentanil consumed by PCIA over 24 hours showed no significant differences among the three groups. Other follow-up data, including ear temperature within 24 hours, incidence of postoperative nausea and vomiting, sore throat, use of additional medications, and length of hospital stay, were comparable across the groups.

Logistic regression analysis

Univariate logistic regression analysis revealed that endotracheal intubation (OR = 2.295, P = 0.001; **Table 5**), anesthesia duration (OR = 1.014, P < 0.001), surgical duration (OR = 1.014, P < 0.001; **Table 5**), and prolonged recovery time (OR = 1.076, P = 0.006; **Table 5**) were independent risk factors for perioperative hypothermia.

Limitations and caveats of the study

The sample selected for this trial may not fully represent all patients undergoing laparoscopic gynecologic surgery across different age groups, disease severity, and baseline physical conditions, limiting the ability to generalize the findings. The study compared only common airway management methods, excluding newer or modified techniques, and preventing a comprehensive assessment of their effect on body temperature regulation. Additionally, as the study was conducted in a specific hospital setting, its applicability to more complex and variable clinical environments is uncertain, possibly limiting the reproducibility of the results in other healthcare settings.

Table 3. Patient perioperative variables

	i group (n = 151)	L group (n = 156)	T group (n = 152)	*P* value	*p* value		
					i group vs. L group	T group vs. i group	T group vs. L group
Perioperative hypothermia, n (%)	32 (21.2)	33 (21.2)	58 (38.2)	< 0.001	0.993	0.001	0.001
Immediate postoperative shivering, n (%)	22 (14.6)	23 (14.7)	34 (22.4)	0.12	0.966	0.08	0.085
Immediate postoperative epistaxis, n (%)	20 (13.2)	16 (10.3)	26 (10.3)	0.212	0.416	0.349	0.08
Duration of anesthesia (min)	110.00 (85.00,137.50)	109.50 (90.00, 137.50)	111.00 (95.00, 141.25)	0.197	0.877	0.122	0.116
Duration of surgery (min)	90.00 (72.50, 141.25)	90.00 (75.00, 141.25)	95.00 (80.00, 141.25)	0.493	0.831	0.263	0.362
Extubation time (min)	5.00 (5.00, 9.00)	5.00 (5.00, 10.00)	7.00 (5.00, 10.00)	< 0.001	0.131	< 0.001	0.019
Recovery time (min)	7.00 (5.00, 10.00)	7.50 (5.00, 10.00)	10.00 (7.00, 12.00)	< 0.001	0.034	< 0.001	< 0.001
Total infused fluid (ml)	1700.00 (1500.00, 2000.00)	1500.00 (1500.00, 2000.00)	1700.00 (1500.00, 2000.00)	0.357	0.237	0.204	0.724
Total irrigation fluid (ml)	1600.00 (1500.00, 2000.00)	1700.00 (1500.00, 2000.00)	1700.00 (1500.00, 2000.00)	0.371	0.150	0.368	0.752
Urine output (ml)	100.00 (65.00, 2000.00)	100.00 (65.00, 200.00)	100.00 (100.00, 200.00)	0.279	0.183	0.904	0.155
Sufentanil (μg)	40.00 (30.00, 40.00)	35.00 (30.00, 40.00)	35.00 (30.00, 40.00)	0.001	< 0.001	0.043	0.106
Remifentanil (μg)	500.00 (400.00, 710.00)	600.00 (400.00, 710.00)	500.00 (397.50, 700.00)	< 0.001	0.004	0.392	< 0.001

Data are expressed as mean ± SD, median (interquartile range) and percentage. BMI: body mass index; i group: i-gel laryngeal mask group; L group: supreme laryngeal mask group; T group: tracheal intubation group. Differences were considered to be statistically significant when $P < 0.05$.

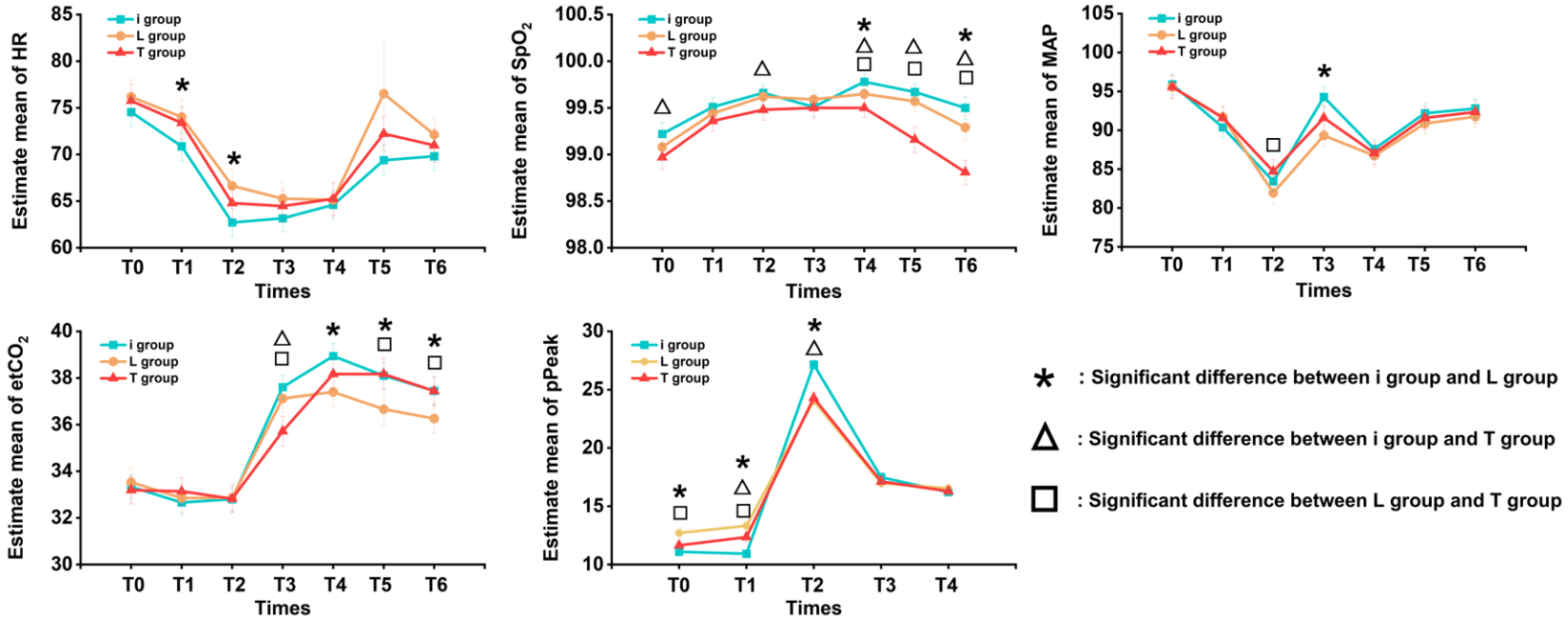

Figure 3. Vital signs and peak airway pressure between the 3 groups. T0: before anesthesia induction; T1: inserted the airway device; T2: surgery begin; T3: pneumoperitoneum established; T4: at the end of surgery; T5: removed the airway device. *: Significant difference between i group and L group ($P < 0.05$), Δ: Significant difference between i group and T group ($P < 0.05$), □: Significant difference between L group and T group ($P < 0.05$).

Another important consideration is the role of airway management decisions and surgical suture techniques. The choice of airway management is typically determined through collaboration between the physician and the patient. Physicians rely on their professional expertise and clinical experience to assess factors such as the urgency of the patient's condition, overall physical status, and anatomical characteristics of the airway, making informed recommendations accordingly. In urgent situations, such as airway obstruction due to severe trauma, physicians must make rapid decisions to establish a secure airway. When patients are conscious and capable of decision-making, physicians provide detailed explanations of the benefits and risks of different airway management options to the patient or their family, incorporating patient preferences into the final decision. Similarly, specialized physicians are well-informed about the advantages and disadvantages of various suture techniques. While medical professionals receive extensive training in airway management and surgical procedures, patients often lack the technical knowledge to fully comprehend the implications of different suture methods. It is expected that physicians will develop comprehensive treatment plans based on clinical guidelines, research evidence, and individual patient factors, selecting the most suitable approach to optimize treatment outcomes, ensure patient safety, and promote optimal recovery.

Discussion

Laparoscopic gynecologic surgery is widely performed in clinical practice due to its minimally invasive nature. However, perioperative hypothermia (core body temperature < 36°C) remains a common complication, with an incidence as high as 30-50%, making it a significant concern among anesthesiologists worldwide [21]. The development of hypothermia is influenced by anesthesia management, surgical procedures, and patient-specific factors. Its consequences include coagulation dysfunction, delayed drug metabolism, increased risk of postoperative infection, and prolonged hospital stays. In anesthesia management, the choice of airway device, such as tracheal intubation or a laryngeal mask, may indirectly affect the ability to maintain body temperature by influencing respiratory gas exchange efficiency, dead space volume, and anesthesia depth regulation.

Tracheal intubation, with its airtight seal, enables precise control of ventilation parameters such as tidal volume and respiratory rate, reducing ineffective ventilation and improving CO_2 elimination. In the context of laparoscopic surgery with CO_2 pneumoperitoneum, tracheal intubation helps maintain stable respiratory mechanics and reduces the risk of hypercapnia, which may otherwise contribute to heat loss through compensatory vasodilation [22]. However, intubation stimulation can increase sympathetic nervous system activity, leading to peripheral vasoconstriction and suppression of non-shivering thermogenesis (NST). A prospective study (n = 120) reported that core body temperature decreased by an average of 0.8 ± 0.3°C one hour after surgery in the tracheal intubation group, significantly less than the decrease observed in the laryngeal mask group (1.2 ± 0.4°C). This difference may be attributed to more efficient CO_2 clearance in the latter. Additionally, tracheal intubation requires deeper anesthesia to suppress the laryngeal reflex, and deep sedation may directly inhibit hypothalamic thermoregulatory function, further reducing NST capacity. Another study found that the rate of intraoperative temperature decline in intubated patients was positively correlated with anesthetic drug dosage, suggesting that deeper sedation may intensify heat loss [23].

The laryngeal mask is often used in conjunction with pressure-supported ventilation (PSV), allowing patients to maintain an autonomous breathing rhythm, which may contribute to increased oxygen consumption and heat production. However, excessively high pneumoperitoneum pressure can lead to CO_2 accumulation, which may accelerate core heat loss through peripheral vasodilation. Studies have shown that in patients using a laryngeal mask,

Table 4. Postoperative evolution of patients in 24 h, and complications throughout hospital stay and length of hospital stay

	i group (n = 151)	L group (n = 156)	T group (n = 152)	*P* value	*p* value		
					i group vs. L group	T group vs. i group	T group vs. L group
Ear temperature (°C)	36.40 (36.00, 36.80)	36.40 (36.00, 36.80)	36.40 (36.10, 36.70)	0.692	0.457	0.456	0.968
Shivering, n (%)	12 (7.9)	13 (8.3)	19 (12.5)	0.326	0.902	0.191	0.231
Postoperative epistaxis, n (%)	9 (6)	7 (4.5)	17 (11.2)	0.058	0.562	0.105	0.028
Nausea and postoperative vomiting, n (%)	31 (20.5)	35 (22.4)	34 (22.4)	0.901	0.684	0.697	0.989
Postoperative sore throat, n (%)	15 (9.9)	11 (7.1)	19 (12.5)	0.274	0.364	0.479	0.107
NRS of pain, at rest	3.00 (2.00, 3.00)	3.00 (2.00, 3.00)	3.00 (2.00, 3.00)	0.299	0.268	0.717	0.135
NRS of pain, with movement	3.00 (3.00, 4.00)	3.00 (2.00, 4.00)	3.00 (2.00, 4.00)	0.054	0.456	0.099	0.019
24 h Sufentanil consumption (ug)	38.00 (33.00, 41.75)	37.00 (32.88, 41.00)	35.00 (30.00, 41.25)	0.507	0.39	0.276	0.722
Other medications within 24 h							
Glucocorticoids, n (%)	5 (3.3)	6 (3.8)	5 (3.3)	0.955	0.801	1	0.792

Data are expressed as mean ± SD, median (interquartile range) and percentage. NRS: numerical rating scale; i group: i-gel laryngeal mask group; L group: supreme laryngeal mask group; T group: tracheal intubation group. Differences were considered to be statistically significant when $P < 0.05$.

Table 5. Logistic regression analysis

Variable	β	SE	z	*P* value	OR (95% CI)
i-gel	0.000				
LMA	-0.002	0.279	-0.008	0.993	0.998 (0.576, 1.729)
tracheal intubation	0.831	0.260	3.196	0.001	2.295 (1.387, 3.849)
Age (yrs)	0.016	0.010	1.637	0.102	1.017 (0.997, 1.037)
BMI (kg/m^2)	-0.037	0.032	-1.176	0.240	0.963 (0.905, 1.025)
ASA, n (%)					
I	0.000				
II	0.140	0.238	0.588	0.557	1.150 (0.725, 1.849)
III	0.270	0.365	0.740	0.459	1.310 (0.629, 2.651)
Mallampati grade, n (%)					
I	0.000				
II	0.499	0.283	1.762	0.078	1.647 (0.962, 2.936)
III	0.087	0.527	0.165	0.869	1.091 (0.362, 2.947)
Hypertension, n (%)					
0	0.000				
1	0.085	0.242	0.354	0.723	1.089 (0.672, 1.737)
Diabetes mellitus, n (%)					
0	0.000				
1	0.125	0.245	0.511	0.609	1.133 (0.695, 1.819)
Coronary heart disease, n (%)					
0	0.000				
1	-0.104	0.351	-0.297	0.766	0.901 (0.436, 1.747)
Total infused fluid (ml)	0.000	0.000	1.860	0.063	1.000 (1.000, 1.001)
Duration of anesthesia (min)	0.014	0.003	5.166	< 0.001	1.014 (1.009, 1.020)
Duration of surgery (min)	0.014	0.003	5.068	< 0.001	1.014 (1.009, 1.020)
Extubation time (min)	0.019	0.032	0.588	0.556	1.019 (0.956, 1.084)
Recovery time (min)	0.073	0.027	2.730	0.006	1.076 (1.021, 1.135)

BMI: body mass index; ASA: American society of anesthesiologists; i group: i-gel laryngeal mask group; L group: supreme laryngeal mask group; T group: tracheal intubation group. Differences were considered to be statistically significant when P < 0.05.

end-tidal CO_2 ($EtCO_2$) is more easily maintained within the physiologic range of 35-45 mmHg during surgery, thereby reducing heat loss associated with hyperventilation. Additionally, because laryngeal mask placement induces less airway irritation, it minimizes peripheral vasoconstriction and helps maintain a more stable thermoregulatory response. The duration of surgery is also closely linked to airway management [24]. During prolonged procedures (> 2 hours), tracheal intubation may slow the rate of temperature decline due to its higher ventilation efficiency. However, for shorter surgeries (e.g., < 1 hour), laryngeal mask ventilation may offer metabolic advantages, leading to better thermoregulation. Therefore, for patients with a shorter expected operative duration and a normal BMI, a laryngeal mask is generally preferred, especially when combined with preoperative warming strategies, such as maintaining an operating room temperature of 24°C, and intraoperative fluid warming [25]. This study explored the effect of perioperative respiratory management on body temperature, addressing a gap in perioperative temperature regulation research.

Findings from this single-center randomized controlled study indicate that patients undergoing tracheal intubation face a higher risk of perioperative hypothermia (PIH) during gynecologic laparoscopic surgery. Body temperature at the end of surgery was significantly lower in the tracheal intubation group compared to the two laryngeal mask groups. The incidence of PIH in the three groups was 21.19%, 21.15%, and 38.16% for the supreme laryngeal mask, i-gel laryngeal mask, and tracheal intubation

groups, respectively. Considering that this study incorporated two active warming strategies, infusion warming and warming pads, these results align with previous studies that implemented similar warming interventions [26-29]. In patients who underwent tracheal intubation, core body temperature decreased by approximately 0.47°C by the end of surgery, a significantly greater drop compared to the supreme and i-gel laryngeal mask groups.

As expected, body temperature declined sharply in all groups during the perioperative period. However, the incidence of hypothermia in the tracheal intubation group was significantly higher than in the two laryngeal mask groups, and core temperature remained lower in the tracheal intubation group compared to the other two groups. Although the core temperature at T10 was lower in the i-gel laryngeal mask group than in the tracheal intubation group, this may have been influenced by the limited data available at that time for the i-gel group. Multiple factors contribute to changes in body temperature under general anesthesia, yet one aspect that has been largely overlooked is heat loss through the respiratory tract, which can account for up to 20% of total energy loss during surgery [17]. The respiratory system plays a critical role in thermoregulation. Previous studies have demonstrated significant temperature fluctuations within the thoracic and pulmonary airways during inhalation. The differences in hypothermia incidence observed in this study may be linked to the capacity for airflow warming and humidification, which varies based on respiratory tract structure [15, 17]. The upper respiratory tract is a key site for regulating the humidity and temperature of inhaled gases, with the nasopharyngeal region playing a particularly important role. Its extensive blood supply, glandular structures, and large mucosal surface area facilitate significant humidification and warming of inspired air. As a result, freshly inhaled air approaches core body temperature and nearly 100% relative humidity before reaching the tracheal bifurcation [17, 30, 31].

Additionally, nasal bleeding was observed in all three groups both immediately after surgery and during the 24-hour follow-up period, which may be linked to placement of the temperature probe. The incidence of postoperative nasal bleeding in the tracheal intubation group was 11.2%, a significant difference compared to the supreme laryngeal mask group. Although these episodes of nasal bleeding did not lead to severe complications, it is essential to remain cautious and consider safer, more comfortable insertion techniques to reduce their occurrence. Regarding postoperative pain, patients in the tracheal intubation group reported higher numerical pain scores during movement compared to those in the i-gel group, which may be associated with a higher incidence of perioperative hypothermia. Although not statistically significant, the incidence of postoperative throat discomfort in the tracheal intubation group was 12.5%, higher than in the two laryngeal mask groups. This finding suggests that, while ensuring patient safety and surgical efficacy, the use of a laryngeal mask may provide additional comfort benefits [32]. Unlike in some previous studies, weconcluded that the occurrence of PIH does not significantly effect postoperative analgesic consumption or the length of hospital stay [33, 34].

We acknowledge several limitations and strengths of this study. First, the findings may not be generalizable to surgeries lasting less than 60 minutes. Second, as this study exclusively focused on female patients undergoing laparoscopic surgery, the results may not apply to other populations, such as males, obese individuals, or patients undergoing open surgery. Third, due to the lack of long-term follow-up beyond 24 hours, we were unable to validate the potential association between PIH and perioperative complications as proposed in other studies. Future research should involve multicenter randomized controlled trials to expand the study population and assess long-term complications associated with mild perioperative hypothermia.

In conclusion, using a laryngeal mask as a perioperative ventilation device offers an effective, simple, and convenient approach that significantly reduces the risk of intraoperative accidental hypothermia in patients undergoing laparoscopic gynecological surgery lasting more than 60 minutes.

Disclosure of conflict of interest

None.

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Table S1. Comparison of perioperative heart rate changes in three groups

	i group (n = 151)	L group (n = 156)	T group (n = 152)	*p* value		
				T group vs. i group	T group vs. i group	T group vs. i group
T0	74.55 (1.57)	76.18 (1.85)	75.76 (1.76)	0.288	0.409	0.768
T1	70.87 (1.59)	74.03 (1.83)	73.38 (1.73)	0.033	0.083	0.638
T2	62.71 (1.50)	66.64 (1.78)	64.79 (1.70)	0.002	0.099	0.146
T3	63.16 (1.45)	65.26 (1.74)	64.47 (1.71)	0.088	0.289	0.532
T4	64.60 (1.48)	65.14 (1.76)	65.25 (1.76)	0.679	0.624	0.935
T5	69.39 (1.58)	76.52 (5.52)	72.23 (1.83)	0.191	0.062	0.425
T6	69.81 (1.53)	72.13 (1.76)	70.98 (1.79)	0.088	0.400	0.398

Note: Data are presented as mean ± SD. T0: Before anesthesia induction; T1: Airway device insertion; T2: Start of surgery; T3: Pneumoperitoneum established; T4: End of surgery; T5: Airway device removal; T6: Before leaving the operating room. Differences were considered to be statistically significant when P < 0.05.

Table S2. Comparison of perioperative MAP changes in three groups

	i group (n = 151)	L group (n = 156)	T group (n = 152)	*p* value		
				T group vs. i group	T group vs. i group	T group vs. i group
T0	95.90 (1.32)	95.57 (1.45)	95.57 (1.47)	0.789	0.794	0.998
T1	90.37 (1.27)	91.70 (1.48)	91.61 (1.44)	0.317	0.334	0.945
T2	83.43 (1.27)	81.94 (1.43)	84.70 (1.55)	0.221	0.346	0.033
T3	94.27 (1.38)	89.32 (1.48)	91.59 (1.55)	< 0.001	0.061	0.087
T4	87.61 (1.23)	86.73 (1.42)	87.06 (1.46)	0.451	0.642	0.777
T5	92.19 (1.27)	90.87 (1.41)	91.59 (1.48)	0.288	0.640	0.550
T6	92.80 (1.26)	91.75 (1.37)	92.35 (1.48)	0.361	0.717	0.594

Note: Data are presented as mean ± SD. T0: Before anesthesia induction; T1: Airway device insertion; T2: Start of surgery; T3: Pneumoperitoneum established; T4: End of surgery; T5: Airway device removal; T6: Before leaving the operating room. Differences were considered to be statistically significant when P < 0.05.

Table S3. Comparison of perioperative oxygen saturation changes in three groups

	i group (n = 151)	L group (n = 156)	T group (n = 152)	*p* value		
				T group vs. i group	T group vs. i group	T group vs. i group
T0	99.22 (0.12)	99.08 (0.13)	98.97 (0.13)	0.251	0.445	0.382
T1	99.51 (0.10)	99.44 (0.12)	99.36 (0.11)	0.460	0.102	0.395
T2	99.66 (0.09)	99.62 (0.10)	99.48 (0.11)	0.542	0.024	0.076
T3	99.51 (0.10)	99.59 (0.10)	99.50 (0.11)	0.339	0.840	0.207
T4	99.78 (0.08)	99.65 (0.10)	99.50 (0.10)	0.006	< 0.001	0.018
T5	99.67 (0.09)	99.57 (0.11)	99.16 (0.14)	0.149	< 0.001	< 0.001
T6	99.50 (0.12)	99.29 (0.13)	98.81 (0.13)	0.045	< 0.001	< 0.001

Note: Data are presented as mean ± SD. T0: Before anesthesia induction; T1: Airway device insertion; T2: Start of surgery; T3: Pneumoperitoneum established; T4: End of surgery; T5: Airway device removal; T6: Before leaving the operating room. Differences were considered to be statistically significant when P < 0.05.

Table S4. Comparison of perioperative $EtCO_2$ changes in three groups

	i group (n = 151)	L group (n = 156)	T group (n = 152)	*p* value		
				T group vs. i group	T group vs. i group	T group vs. i group
T0	33.33 (0.50)	33.53 (0.60)	33.19 (0.58)	0.643	0.753	0.436
T1	32.66 (0.50)	32.85 (0.61)	33.14 (0.58)	0.668	0.276	0.524
T2	32.80 (0.50)	32.86 (0.59)	32.82 (0.58)	0.885	0.964	0.919
T3	37.61 (0.51)	37.12 (0.58)	35.72 (0.64)	0.266	< 0.001	0.006
T4	38.94 (0.55)	37.40 (0.63)	38.17 (0.64)	0.004	0.142	0.167
T5	38.10 (0.56)	36.66 (0.67)	38.17 (0.68)	0.017	0.914	0.020
T6	37.45 (0.56)	36.26 (0.62)	37.44 (0.63)	0.027	0.976	0.027

Note: Data are presented as mean ± SD. T0: Before anesthesia induction; T1: Airway device insertion; T2: Start of surgery; T3: Pneumoperitoneum established; T4: End of surgery; T5: Airway device removal; T6: Before leaving the operating room. Differences were considered to be statistically significant when P < 0.05.

Table S5. Comparison of perioperative P_{Peak} changes in three groups

	i group (n = 151)	L group (n = 156)	T group (n = 152)	*p* value		
				T group vs. i group	T group vs. i group	T group vs. i group
T1	11.09 (0.35)	12.70 (0.41)	11.64 (0.40)	< 0.001	0.074	0.001
T2	10.92 (0.35)	13.32 (0.40)	12.35 (0.39)	< 0.001	< 0.001	0.002
T3	27.15 (0.38)	24.06 (0.41)	24.29 (0.44)	< 0.001	< 0.001	0.547
T4	17.48 (0.42)	16.97 (0.43)	17.12 (0.45)	0.188	0.386	0.727
T5	16.21 (0.35)	16.53 (0.40)	16.29 (0.41)	0.287	0.807	0.466

Note: Data are presented as mean ± SD. T1: Airway device insertion; T2: Start of surgery; T3: Pneumoperitoneum established; T4: End of surgery; T5: Airway device removal. Differences were considered to be statistically significant when P < 0.05.