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Original Scientific Paper

AIRWAY MANAGEMENT IN LAPAROSCOPIC CHOLECYSTECTOMY – A COMPARATIVE ANALYSIS

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SUMMARY – In this study, we aimed to compare supraglottic airway devices (Supreme and i-gel laryngeal mask) with tracheal tube with respect to airway control and efficiency in ventilation and oxygenation. The study included 325 patients of ASA I-II who underwent laparoscopic cholecystectomy. In group 1, the airway was secured using endotracheal intubation (115 patients). In group 2 (103 patients), LMA Supreme was applied, whereas i-gel mask was used for airway management in group 3 (107 patients). Monitoring parameters were recorded and compared using t-test, analysis of variance (ANOVA), Tukey's test and χ2-test. The following parameters were monitored: insertion time, number of attempts for device placement, oropharyngeal seal pressure, etc. Insertion time was longest in group 1 (14.7±1.65 s) as compared to group 2 (15.5±1.05 s) and group 3 (14.1±1.27 s); ANOVA test yielded a statistically significant difference ($p<0.01$). Insertion success rate was almost identical in all three groups ($p=0.907$, χ2-test). Comparison of oropharyngeal seal pressure between group 2 (35.95±2.92 cm H2O) and group 3 (36.47±1.43 cm H_2O) yielded no statistical difference ($p=0.314$, t-test). Endotracheal tube, Supreme and i-gel laryngeal masks were shown to be equally efficient in airway management in laparoscopic cholecystectomy. All three devices enabled efficient ventilation and oxygenation despite certain pathophysiological changes associated with laparoscopy.

Key words: *Endotracheal tube; Laryngeal mask; Airway; Laparoscopic cholecystectomy*

Introduction

Despite significant advantages, laparoscopic surgery imposes certain problems related to specific pathophysiological changes. Patient positioning (Trendelenburg and reverse Trendelenburg), an increase in the intra-abdominal pressure (IAP) and CO_2-induced pneumoperitoneum can significantly impair cardiovascular and respiratory systems[1].

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However, the pathophysiological changes in patients of American Society of Anesthesiologists (ASA) I-II undergoing laparoscopic surgery do not have major effect on anesthetic management or recovery. Laparoscopic operations are commonly performed under general anesthesia with intermittent positive pressure ventilation (IPPV). In this setting, a variety of anesthetic techniques can be opted for, e.g., balanced anesthesia, inhaled anesthetics, and total intravenous anesthesia (TIVA).

Endotracheal intubation remains the gold standard procedure for airway management. In 1980, Archie Brain introduced laryngeal mask as a new device for securing the upper airway. Its introduction into clinical practice coincided with the increasing number of laparoscopic procedures in general surgery and gynecologic practice. However, the use of classic type laryngeal mask (LMA Classic) in laparoscopy remains controversial due to the increased risk of regurgitation and pulmonary aspiration. The emergence of new supraglottic airway devices (SAD) with better characteristics (better laryngeal, perilaryngeal and hypopharyngeal seal, less gas leakage, single patient use, presence of a drainage channel, etc.) has reawakened interest in these devices for airway management in laparoscopy. New SADs offer a range of advantages over endotracheal intubation (ease and speed of placement, stable hemodynamics, favorable respiratory mechanics, lower incidence of complications, smooth emergence)[2-4].

These airway devices with access gastric tubes are increasingly being used in surgery requiring general anesthesia and positive pressure ventilation. Nevertheless, anesthesia still poses a risk of changes in respiratory mechanics, given that pneumoperitoneum and reverse Trendelenburg position followed by an increase in peak (P_{peak}) and plateau (P_{plat}) pressures can lead to high oropharyngeal leak pressure, gastric insufflation, regurgitation, and subsequent pulmonary aspiration[5,6]. Also, there are doubts that a SAD can maintain sufficient intraoperative ventilation and adequate oxygenation in procedures requiring diametrically opposite patient positioning. This study aimed to compare SADs (i-gel laryngeal mask and LMA Supreme (LMAs)) with endotracheal intubation with respect to airway control and efficiency in ventilation and oxygenation.

Patients and Methods

This study was conducted in Gračanica Clinical Center and Leskovac Hospital. Written informed consent was obtained from patients and the study was conducted in a prospective, controlled, and randomized fashion in the 2013-2018 period. The study included 325 patients of ASA I-II who underwent laparoscopic cholecystectomy. Subjects were randomly assigned to three groups following simple randomization procedures (computerized random numbers). In group 1, 115 patients were assigned to have endotracheal intubation (ETT) for airway management. In group 2 of 103 patients, LMA Supreme (LMAs) was applied, whereas i-gel laryngeal mask was used in 107 patients assigned to group 3. All interventions were performed under general anesthesia with controlled ventilation.

We recorded age and body weight in all enrolled patients. Those with an increased risk of aspiration (pregnancy, hiatus hernia, undigested food, gastroesophageal reflux disease, diabetes*)* or potentially difficult intubation (face and neck deformities, body mass index (BMI) >30, Mallampati >2, inter-incisor gap <3.5 cm) were excluded from the study.

Induction and maintenance of anesthesia

Preoperative care included elastic bandaging of lower limbs and administration of low-molecular-weight heparin two hours prior to operation in order to prevent thromboembolic complications. To prevent hemodynamic instability, patients were administered 10 mL/kg body weight (b.w.) of crystalloid infusion. Anesthesia and premedication were standardized for all patients. Patients were premedicated with intramuscular midazolam 0.1 mg/kg b.w., intramuscular atropine 0.5 mg, and intravenous ranitidine 1 mg/kg b.w. Patients were pre-oxygenated using oxygen flow rates of 6 L/min over 3 minutes. Anesthetic induction was provided *via* intravenous propofol 2 mg/kg b.w. A dose of 0.9 mg/kg b.w. rocuronium bromide was administered to provide skeletal muscle relaxation. The airway device was placed after waiting for the appropriate period for muscle relaxation. Following insertion, patient head was stabilized in neutral position, the cuff of the LMAs device was air-inflated to a pressure of 60 cm H_2O, and the cuff pressure was maintained at 60 cm H_2O throughout the procedure using a cuff monitor (Portex Pressureeasy Cuff Pressure Monitor 10/cs). The SAD dimension was selected according to patient body weight. To facilitate easy passage into the trachea, the largest diameter endotracheal tube was selected. Airway devices were inserted by the experienced anesthesiologist. The interventions were performed under TIVA. In all three groups, anesthesia was maintained using a target-controlled infusion pump (Perfusor Compact-Braun) delivering remifentanil 0.1-1.0 μg/kg/min and propofol 75-150 μg/kg/min. Repeated dosage of 0.15 mg/kg b.w. rocuronium bromide was used as muscle relaxant.

The inspiratory mixture of oxygen and medical air at flow rates of 1.5 L/min and 4 L/min, respectively, delivered the inspired oxygen concentration of 40% (FiO_2 0.4). After completion of the procedure, anesthesia was discontinued and residual neuromuscular blockade was reversed with neostigmine methyl sulfate 0.05 mg/kg b.w. and atropine sulfate 0.015 mg/kg b.w. The airway device was removed when the patient was conscious, started spontaneous respiration (adequate tidal volume, minute volume, SaO_2 >92%), could move muscle against gravity, and hemodynamic parameters did not deviate by more than 20% compared to the initial values.

Initial ventilator settings

Patients in all three groups received mechanical ventilation with IPPV mode (tidal volume of 8 mL/kg b.w., frequency of 12/min, positive end expiratory pressure (PEEP) of 5 cm H_2O and inspiratory to respiratory (I:E) ratio of 1:2. End tidal carbon dioxide ($EtCO_2$) was measured to assess ventilation efficiency. $EtCO_2$ of 30-45 mm Hg indicated sufficient ventilation during the procedure. Patients undergoing laparoscopic cholecystectomy were placed in reverse Trendelenburg position with 15-degree left lateral tilt. Pneumoperitoneum was created using CO_2 as an insufflating agent, and maintained at 13 mm Hg of IAP.

Monitoring

Standard monitoring included oxygen saturation (SaO_2), partial pressure of oxygen in arterial blood (PaO_2), capnography, partial pressure of carbon dioxide in arterial blood ($PaCO_2$), peak inspiratory pressure (P_{peak}), tidal volume (Vt), electrocardiography (ECG), and mean arterial pressure (MAP). In addition to standard monitoring parameters, we also recorded the following:

- insertion time (insertion time was defined as the interval between picking up the ETT, i-gel mask or LMA_S and obtaining an effective airway);
- number of attempts for device placement/intubation;
- operating time;
- duration of carbon dioxide pneumoperitoneum; and
- oropharyngeal seal pressure (OSP). OSP was identified by closing the expiration valve of the circle system at a constant gas flow of 5 L/min (peak airway pressure was allowed as a maximum of 40 cm H_2O).

Parameters were analyzed at the following intervals: T_0 – baseline, T_1 – after induction to anesthesia, T_2 – 5 min after creating pneumoperitoneum, T_3 – 30 min after introducing pneumoperitoneum, and T_4 – 5 min after discontinuing pneumoperitoneum and the patient's position had returned to supine.

Ethics

The study was conducted after obtaining a written approval from Ethics Committee of Gračanica Clinical Center and Leskovac Hospital. Patients received a written notice that outlined the purpose of research, and they signed the consent form to participate in the research. Patient participation in the research was voluntary and anonymous.

Statistical analysis

Analysis of the data obtained was performed using the SPSS 22.0 software (Version 22.0, SPSS, Inc., Chicago, IL, USA), as well as Microsoft Excel 2010. Descriptive statistics was used to determine relative numbers and measures of central tendency, i.e., arithmetic mean (χ), a measure of variability (standard deviation, SD) and relative proportions (percentages).

Monitored parameters were recorded and compared using Student's t-test, χ^2-test, ANOVA test and Tukey's Honestly Significant Difference (HSD) post-hoc test (Tukey's range test). The values of $p>0.05$ were considered statistically nonsignificant, $p<0.05$ were considered statistically significant, and $p<0.01$ were considered statistically highly significant on all comparisons.

Results

Data analysis yielded no statistically significant difference (Table 1) among the groups with respect to body weight (p=0.0007, ANOVA test), ASA classification (p=0.519, χ^2-test) and age (p=0.015, ANOVA test).

Study results revealed a statistically significant difference (p>0.01, ANOVA test) among the devices applied in insertion time, duration of operation and duration of pneumoperitoneum. The χ^2-test did not reveal statistical significance in the number of attempts for correct placement of ETT, LMAs and i-gel mask (p=0.291) (Table 2).

Oropharyngeal seal pressure (Table 3) was slightly higher in i-gel group (36.4±3.4 cm H_2O) compared to LMAS group (35.9±2.9 cm H_2O). T-test revealed no statistical significance (p=0.252).

Table 1. Statistical data analysis of patient body weight, age and ASA affiliation

Groups	ETT	LMAs	i-gel	p-value
Body weight, kg (mean ± SD)	57.8±8.2	60.4±7.3	55.9±9.8	0.0007 (ANOVA)
Age, years (mean ± SD)	45.8±7.5	42.7±7.6	44.2±8.7	0.015 (ANOVA)
ASA I/ASA II/total	85/30/115	77/30/107	81/22/103	0.519 (χ^2-test)

ASA = American Society of Anesthesiologists; ETT = endotracheal tube; LMAs = Supreme laryngeal mask; i-gel = i-gel laryngeal mask; SD = standard deviation; p>0.05 nonsignificant; p<0.05 significant; p<0.01 highly significant

Table 2. Statistical data analysis of insertion time, attempts, duration of operation, and duration of pneumoperitoneum

Group	ETT	LMAs	i-gel	p-value
Size (mm)	7.0	4	4	
Insertion time, s (mean ± SD)	14.7±1.6	15.5±1.1	14.1±1.3	<0.01 (ANOVA)
t-test (p-value)	ETT *vs.* LMAs (0.0001)	LMAs *vs.* i-gel (0.0001)	ETT *vs.* i-gel (0.0029)	
Number of attempts (1/2/3/failed)	101/11/4/0	88/12/7/0	92/10/1/0	0.291 (χ^2-test)
Duration of operation, min (mean ± SD)	70.1±12.3	75.7±8.5	62.1±16.4	<0.01 (ANOVA)
t-test (p-value)	ETT *vs.* LMAs (0.0001)	LMAs *vs.* i-gel (0.0001)	ETT *vs.* i-gel (0.0001)	
Duration of p.p., min (mean ± SD)	44±10.2	41±8.4	47±7.4	<0.01 (ANOVA)
t-test (p-value)	ETT *vs.* LMAs (0.0181)	LMAs *vs.* i-gel (0.0001)	ETT *vs.* i-gel (0.0147)	

ETT = endotracheal tube; LMAS = Supreme laryngeal mask; i-gel = i-gel laryngeal mask; SD = standard deviation; s = seconds; min = minutes; p.p. = pneumoperitoneum; p>0.05 nonsignificant; p<0.05 significant; p<0.01 highly significant

Table 3. Statistical analysis of data on oropharyngeal seal pressure

Group	LMAs	i-gel mask	p-value
OSP, cm H_2O (mean ± SD)	35.9±2.9	36.4±3.4	0.252 (t-test)

OSP = oropharyngeal seal pressure; LMAs = Supreme laryngeal mask; i-gel = i-gel laryngeal mask; SD = standard deviation; p>0.05 nonsignificant; p<0.05 significant; p<0.01 highly significant

After induction to anesthesia, securing an open airway and producing pneumoperitoneum using CO_2 insufflation into the peritoneal cavity, there was an increase in P_{peak} and decrease in lung compliance over T_1-T_3 monitoring intervals in all study groups. The highest P_{peak} was recorded in ETT group; somewhat lower values were recorded in LMAs and i-gel mask groups. The most notable decrease in lung compliance over time intervals was recorded in ETT group (Table 4). Statistical analysis of the recorded values for P_{peak} and lung compliance using ANOVA test revealed high significance (p<0.01) over all time intervals (T_1-T_4). Tukey's HSD post hoc test revealed significant difference (p<0.01) on comparison of ETT *vs.* LMAs and ETT *vs.* i-gel group (Table 4).

Table 4. Mean values of peak of pressure (P_{peak}) and pulmonary dynamic compliance (C_{dyn}) by time stages of research and significance of differences between study groups

Parameter	P_{peak}, cm H_2O (mean ± SD)				C_{dyn}, mL/cm H_2O (mean ± SD)			
Group	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
ETT	17.8±2.4	23.8±1.9	25.6±1.4	19.7±2.1	46.3±10.3	32.6±5.5	24.4±13.5	39.1±16.2
LMA_s	14.4±2.2	17.6±1.5	22.3±1.1	16.4±2.3	59.4±14.6	40.1±8.5	31.4±11.7	47.3±18.7
i-gel	14.7±1.9	18.1±1.8	21.7±2.8	16.9±2.4	64.1±18.3	42.7±10.7	34.5±14.8	52.2±13.4
ANOVA (p-value)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tukey's Honest Significant Difference (HSD) post-hoc test (p-value)								
ETT *vs.* LMAs	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ETT *vs.* i-gel	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LMAs *vs.* i-gel	0.58	0.096	0.057	0.247	0.053	0.066	0.214	0.075

ETT = endotracheal tube; LMAs = Supreme laryngeal mask; i-gel = i-gel laryngeal mask; SD = standard deviation; p>0.05 nonsignificant; p<0.05 significant; p<0.01 highly significant

After induction to anesthesia, muscle relaxation and initiation of controlled mechanical ventilation, there was a decrease in $PaCO_2$ and $EtCO_2$ (T_1). Creation and duration of pneumoperitoneum (T_{2-3}) caused an increase in $PaCO_2$ and $EtCO_2$ under conditions of constant ventilation. Analysis of the recorded mean values of $PaCO_2$ and $EtCO_2$ over monitoring intervals (T) revealed no statistical significance (p>0.05, ANOVA test; Tukey's range test) among the study groups (Table 5).

Table 5. Mean values of arterial partial pressure of carbon dioxide ($PaCO_2$) and end-tidal CO_2 ($EtCO_2$) by time stages of research and significance of differences between study groups

Parameter	$PaCO_2$, mm Hg (mean ± SD)					$EtCO_2$, mm Hg (mean ± SD)				
	T-interval									
Group	T_0	T_1	T_2	T_3	T_4	T_0	T_1	T_2	T_3	T_4
ETT	38±7.1	32±4.6	36±4.8	43±2.1	37±4.5	35±3.6	28±2.3	33±4.5	40±7.8	35±8.2
LMA_s	37±5.1	31±2.3	36±5.2	44±4.6	36±4.3	34±4.2	29±2.5	32±3.4	39±4.9	33±6.1
i-gel	39±6.4	32±2.1	35±4.5	43±3.2	37±4.1	35±3.4	28±2.7	32±3.2	38±6.5	34±6.5
ANOVA (p)	0.071	0.072	0.225	0.061	0.121	0.079	0.185	0.074	0.08	0.107
Tukey's Honest Significant Difference (HSD) post-hoc test (p-value)										
ETT *vs.* LMAs	0.462	0.108	0.994	0.095	0.167	0.117	0.239	0.12	0.491	0.087
ETT *vs.* i-gel	0.469	0.994	0.282	0.994	0.994	0.994	0.994	0.125	0.064	0.546
LMAs *vs.* i-gel	0.055	0.122	0.294	0.107	0.184	0.131	0.257	0.994	0.51	0.558

ETT = endotracheal tube; LMAs = Supreme laryngeal mask; SD = standard deviation; i-gel = i-gel laryngeal mask; p>0.05 nonsignificant; p<0.05 significant; p<0.01 highly significant

Comparison of the mean values of PaO_2 and SaO_2 (Table 6), heart rate and MAP (Table 7), revealed no significant differences between the groups (ANOVA test; Tukey's range test).

Table 6. Mean values of arterial partial pressure of oxygen (PaO_2) and oxygen saturation (SaO_2) by time stages of research and significance of differences between study groups

Parameter	PaO_2, mm Hg (mean ± SD)					SaO_2, % (mean ± SD)				
	T-interval									
Group	T_0	T_1	T_2	T_3	T_4	T_0	T_1	T_2	T_3	T_4
ETT	90±8	144±17	139±17	139±31	141 ±18	96.1±3.5	98.9±1.9	98.9±2.1	98.5±1.2	98.7±2.3
LMAs	88±11	147±24	134±28	131±26	135 ±29	95.6±4.2	99±1.5	98.6±2.4	98.5±1.4	98.4±2.6
i-gel	88±9	150±19	139±24	135±19	137 ±26	96.3±3.7	99.1±1.9	98.7±2.7	98.7±1.3	98.6±2.6
ANOVA (p)	0.186	0.091	0.193	0.073	0.181	0.387	0.709	0.637	0.435	0.663
Tukey Honestly Significant Difference (HSD) post-hoc test (p-value)										
ETT *vs.* LMS	0.253	0.509	0.248	0.058	0.166	0.591	0.907	0.621	0.994	0.644
ETT *vs.* i-gel	0.26	0.073	0.994	0.494	0.455	0.96	0.685	0.812	0.493	0.953
LMAs *vs.* i-gel	0.994	0.528	0.267	0.506	0.826	0.378	0.912	0.951	0.505	0.83

ETT = endotracheal tube; LMAs = Supreme laryngeal mask; i-gel = i-gel laryngeal mask; SD = standard deviation; p>0.05 nonsignificant; p<0.05 significant; p<0.01 highly significant

Table 7. Mean values of heart rate and mean arterial pressure (MAP) by time stages of research and differences between study groups

Parameter	Heart rate/min (mean ± SD)					MAP, mm Hg (mean ± SD)				
	T-interval									
Group	T_0	T_1	T_2	T_3	T_4	T_0	T_1	T_2	T_3	T_4
ETT	82±12	83±11	88±15	82±12	82±19	99±19	81±16	117±14	100±17	97±9
LMAs	79±11	80±14	89±12	84±8	78±17	96±15	79±12	114±17	98±6	97±16
i-gel	79±10	80±11	88±11	84±13	77±13	94±12	82±16	117±13	97±15	98±8
ANOVA (p)	0.0667	0.1024	0.8051	0.3076	0.062	0.0621	0.3259	0.2289	0.252	0.7681
Tukey's Honest Significant Difference (HSD) post-hoc test (p-value)										
ETT *vs.* LMS	0.109	0.155	0.831	0.38	0.174	0.331	0.573	0.286	0.518	0.994
ETT *vs.* i-gel	0.114	0.16	0.984	0.387	0.069	0.051	0.872	0.994	0.237	0.798
LMAs *vs.* i-gel	0.994	0.994	0.839	0.994	0.9	0.627	0.307	0.305	0.855	0.805

ETT = endotracheal tube; LMAs = Supreme laryngeal mask; i-gel = i-gel laryngeal mask; SD = standard deviation; p>0.05 nonsignificant; p<0.05 significant; p<0.01 highly significant

Discussion

This study compared endotracheal tube with supraglottic airway devices (LMA_S and i-gel laryngeal mask) in terms of safety and efficiency in securing the airway during laparoscopic cholecystectomy. In laparoscopic cholecystectomies, studies have suggested endotracheal intubation – one of the most commonly applied general surgery procedures – as airway management. However, one retrospective and three prospective studies claim that classic LMAs is a suitable alternative. As for the ProSeal laryngeal mask (PLMA), it is more effective than classic LMA since it includes a gastric channel[7]. One study found that no gastric distention was caused by laparoscopic cholecystectomy with properly placed PLMA, which ventilates in equal affectivity to the endotracheal tube[8]. Carron *et al*. described one patient with severe pulmonary fibrosis who had elective laparoscopic cholecystectomy; they ensured airway control with LMAS and stated that there was less airway resistance[9].

Our study results showed statistical significance in insertion time between LMAs and i-gel mask; however, it was of no clinical significance. Gupta *et al*. also report similar results. Insertion time for LMAs was significantly longer than that for i-gel (12.5 ± 2.35 *vs*. 11.07 ± 1.93 seconds)[10]. Other authors conclude that LMAs and i-gel mask have similar clinical performance and insertion success rate in simulated difficult airway[11]. Insertion success rate on the first attempt was similar with all three devices (90%-95%) used for airway control in laparoscopic surgical procedures. The high insertion success rate on the first attempt can be attributed to favorable intubating conditions provided by total intravenous anesthesia and degree in experience and skill of the performing anesthesiologist. This observation coincides with the results of other studies on this subject[12-16].

Oropharyngeal seal pressure did not differ between the devices when the inflatable devices had a cuff pressure of 60 cm H_2O. The OSP determined for the i-gel mask and LMAs was similar to those described previously[17-20]. In our study, we measured OSP in regular intervals from the start until completion of the surgery and found it to be similar at all time points. OSP was slightly higher with the use of LMAs compared to i-gel. These OSP values indicate adequate laryngeal and perilaryngeal seal with sufficient intraoperative ventilation during laparoscopic operations.

Insufflation of CO_2 and formation of pneumoperitoneum further impair pulmonary function during a laparoscopic procedure, causing increased pulmonary resistance and decreased thoracopulmonary compliance[21,22]. The results obtained in this study showed that the highest P_{peak} was recorded with the use of ETT, compared to considerably lower values in LMAs and i-gel groups. This can be explained by the smaller inside diameter of ETT compared to LMAs and i-gel mask. Other factors that influence the increased P_{peak} during laparoscopic procedures are anesthesia with complete striated muscle relaxation, intraoperative patient position, and CO_2 induced pneumoperitoneum.

However, this increase in P_{peak} with constant minute ventilation and tidal volume was significantly lower when compared to OSP values in the LMAs and i-gel groups and did not affect ventilation efficiency. The reported OSP values were not significantly changed after the creation of pneumoperitoneum. The above factors that led to an increase in P_{peak} in the course of the procedure caused a decrease in dynamic pulmonary compliance. A decrease in pulmonary compliance was also observed in other groups, but to a lesser extent.

Carbon dioxide is the most frequently used gas for insufflation of the abdomen as it is colorless, non-toxic, non-flammable, and has the greatest margin of safety in the event of venous embolus (highly soluble). It is absorbed readily from the peritoneum, causing an increase in $PaCO_2$. Intraoperative pulmonary ventilation model (IPPV) secured sufficient ventilation with $PaCO_2$ and $EtCO_2$ maintained in the range of normal physiological values. Following the airway device insertion and mechanical ventilation (T_1), there was a decrease in $PaCO_2$ and $EtCO_2$ caused by moderate hyperventilation. Intraperitoneal CO_2 insufflation led to absorption of CO_2 from the peritoneum, causing the increase in $PaCO_2$ and $EtCO_2$. This increase was maintained within physiological limits as it was dependent on the duration of pneumoperitoneum in both groups. In laparoscopic surgery, as a result of the increase in IAP, early closure in small airways and an increase in peak airway can be seen. In this case, an increase in $EtCO_2$ can develop with no variation in SaO_2[23]. Whatever the mechanical effect of pneumoperitoneum, given that the vast majority of laparoscopic procedures are performed by inflating CO_2 into the abdomen, the main use of $EtCO_2$ during laparoscopic procedures is to indirectly assess the rise of $PaCO_2$ over time and to titrate minute ventilation[24,25].

The reported values of oxygenation parameters (PaO_2 and SaO_2) were within the normal limits during surgery. The application of a constant positive airway pressure of 5 cm H_2O preserves arterial oxygenation during prolonged pneumoperitoneum[26,27]. There are few respiratory effects in the reverse Trendelenburg (head up) position but more marked effects on the cardiovascular system. A decrease in venous return results in decreased cardiac output and therefore blood pressure. These effects are more marked in a patient who is hypovolemic or cardiovascularly compromised. Increased IAP affects venous return, systemic vascular resistance and myocardial function. Initially, owing to autotransfusion of pooled blood from the splanchnic circulation, there is an increase in the circulating blood volume, resulting in an increase in venous return and cardiac output[28]. However, further increases in the IAP result in compression of the inferior vena cava, reduction in venous return, and subsequent decrease in cardiac output[29]. Adequate perioperative hydration and TIVA provided hemodynamic stability. Inter-group comparison did not show statistically significant difference with respect to heart rate and MAP between the groups.

Conclusion

Endotracheal tube, LMA Supreme and i-gel laryngeal mask were shown to be equally efficient in managing the airway in patients undergoing laparoscopic cholecystectomy. All studied devices secured efficient ventilation and oxygenation despite specific pathophysiological changes associated with laparoscopy. Statistical differences in the insertion time and peak inspiratory pressure did not bear any clinical significance.

References

1. Calland JF, Tanaka K, Foley E, Bovbjerg VE, Markey DW, Blome S, *et al*. Outpatient laparoscopic cholecystectomy: patient outcomes after implementation of a clinical pathway. Ann Surg. 2001;233(5):704-15. PMID: 11323509.
2. Dyer RA, Llewellyn RL, James MFM. Total i.v. anaesthesia with propofol and the laryngeal mask for orthopaedic surgery. Br J Anaesth. 1995;74:123-8. PMID: 7696057.
3. Richez B, Saltel L, Banchereau F, Torrielli R, Cros AM. A New single use supraglottic device with a noninflatable cuff and an esophageal vent: an observational study of the i-gel. Anesth Analg. 2008;106:1137-9. DOI: 10.1213/ane.0b013e318164f062. PMID: 18349185.
4. Higgins PP, Chung F, Mezei G. Postoperative sore throat after ambulatory surgery. Br J Anaesth. 2002;88:582-4. PMID: 12066737.
5. Sidaras G, Hunter JM. Is it safe to artificially ventilate a paralysed patient through the laryngeal mask? The jury is still out. Br J Anaesth. 2001;86(6):749-53. PMID: 11573579.
6. Cooper RM. The LMA, laparoscopic surgery and the obese patient can *vs*. should. Can J Anaesth. 2003;50:5-10. PMID: 12514142.
7. Lu PP, Brimacombe J, Yang1 C, Shyr M. ProSeal *versus* the classic laryngeal mask airway for positive pressure ventilation during laparoscopic cholecystectomy. Br J Anaesth. 2002;88:824-7. PMID: 12173201.
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 Anesth. 2002;49:857-62. DOI: 10.1007/BF03017420. PMID: 12374716.
9. Carron M, Marchet A, Ori C. Supreme laryngeal mask airway for laparoscopic cholecystectomy in patient with severe pulmonary fibrosis. Br J Anaesth. 2009;103:778-9. DOI: 10.1093/bja/aep288. PMID: 19837815.
10. Gupta V, Mehta N, Gupta S, Mahotra K. Comparative evaluation supraglottic airway devices I-gel *versus* LMA Supreme in patients undergoing surgery under general anaesthesia. Indian J Clin Anaesth. 2015;2(2):86-91. DOI: 10.5958/2394-4994.2015.00004.9.
11. Theiler LG, Brueggeney MK, Kaiser D, Urwyler N, Luyet C, Vogt A, *et al*. Crossover comparison of the laryngeal mask supreme and the I gel in simulated difficult airway scenario in anesthetized patients. Anesthesiology. 2009;111:55-62. DOI: 10.1097/ALN.0b013e3181a4c6b9. PMID: 19512881.
12. 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. PMID: 12173201.
13. Sharma B, Sehgal R, Sahai C, Sood J. PLMA *vs*. I-gel: A comparative evaluation of respiratory mechanics in laparoscopic cholecystectomy. J Anaesthesiol Clin Pharmacol. 2010;26:451-7. PMID: 21547168.
14. Abdi W, Amathieu R, Adhoum A, Poncelet C, Slavov V, Kamoun W, *et al*. Sparing the larynx during gynecological laparoscopy: a randomized trial comparing the LMA Supreme and the ETT. Acta Anaesthesiol Scand. 2010;54(2):141-6. DOI: 10.1111/j.1399-6576.2009.02095.x. PMID: 19681772.
15. Beleña JM, Gracia JL, Ayala JL, Núñez M, Lorenzo JA, de los Reyes A, *et al*. The Laryngeal Mask Airway Supreme for positive pressure ventilation during laparoscopic cholecystectomy. J Clin Anesth. 2011;23:456-60. DOI: 10.1016/j.jclinane.2011.01.004. PMID: 219111191.
16. Hoşten T, Yıldız TŞ, Kuş A, Solak M, Toker K. Comparison of Supreme Laryngeal Mask Airway and ProSeal Laryngeal Mask Airway during cholecystectomy. Balkan Med J.

2012;29:314-9. DOI: 10.5152/balkanmedj.2012.001. PMID: 25207022.

17. Russo1 GS, Cremer1 S, Galli T, Eich C, Bräuer A, Crozier AT, *et al*. Randomized comparison of the i-gel™, the LMA Supreme™, and the Laryngeal Tube Suction-D using clinical and fibreoptic assessments in elective patients. BMC Anesthesiology. 2012;12:18. DOI: 10.1186/1471-2253-12-18. PMID: 22871204.
18. Gatward JJ, Cook TM, Seller C, Handel J, Simpson T, Vanek V, *et al*. Evaluation of the size 4 i-gel airway in one hundred non-paralysed patients. Anaesthesia. 2008;63(10):1124-30. DOI: 10.1111/j.1365-2044.2008.05561.x. PMID: 18616521.
19. Teoh WH, Lee KM, Suhitharan T, Yahaya Z, Teo MM, Sia AT. Comparison of the LMA Supreme *vs* the i-gel in paralysed patients undergoing gynaecological laparoscopic surgery with controlled ventilation. Anaesthesia. 2010;65(12):1173-9. DOI: 10.1111/j.1365-2044.2010.06534.x. PMID: 20958278.
20. Timmermann A, Cremer S, Eich C, Kazmaier S, Brauer A, Graf BM, *et al*. Prospective clinical and fiberoptic evaluation of the Supreme laryngeal mask airway. Anesthesiology. 2009;110 (2):262-5. DOI: 10.1097/ALN.0b013e3181942c4d. PMID:19194153.
21. Beleña MJ, Ochoa JE, Núñez M, Gilsanz C, Vidal A. Role of laryngeal mask airway in laparoscopic cholecystectomy. World J Gastrointest Surg. 2015;7(11):319-25. DOI: 10.4240/wjgs.v7.i11.319. PMID: 26649155.
22. Jang YK, Hong JS, Lim KH, Um JD. Change of respiratory mechanics at different IAPs and position change during laparoscopic surgery. Korean J Anesthesiol. 2013;64(6):560-1. DOI: 10.4097/kjae.2013.64.6.560.
23. 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. DOI: 10.1097/MD.0000000000004598 PMID: 20661199.
24. Blobner M, Felber AR, Gogler S, Feussner H, Weigl EM, Jelen G, *et al*. The resorption of carbon dioxide from the pneumoperitoneum in laparoscopic cholecystectomy. Anaesthesist. 1993;42:288-94. PMID: 8317685.
25. Wurst H, Schulte-Steinberg H, Finsterer U. Pulmonary CO2 elimination in laparoscopic cholecystectomy. A clinical study. Anaesthesist. 1993;42:427-34. PMID: 8363026.
26. Meininger D, Byhahn C, Mierdl S, Westphal K, Zwissler B. Positive end-expiratory pressure improves arterial oxygenation during prolonged pneumoperitoneum. Acta Anaesthesiol Scand. 2005;49(6):778-83. DOI: 10.1111/j.1399-6576.2005.00713.x. PMID: 15954959.
27. Kim JY, Shin CS, Kim HS, Jung WS, Kwak HJ. Positive end-expiratory pressure in pressure-controlled ventilation improves ventilatory and oxygenation parameters during laparoscopic cholecystectomy. Surg Endosc. 2010;24(5):1099-103. DOI: 10.1007/s00464-009-0734-6. PMID:19915912.
28. Perrin M, Fletcher A. Laparoscopic abdominal surgery. Continuing Education in Anaesthesia Critical Care & Pain. BJA. 2004;4(4):107-10. DOI: 10.1093/bjaceaccp/mkh032.
29. Barker L. Positioning on the operating table. Update Anaesth. 2002;15:1-6.

Sažetak

UPRAVLJANJE DIŠNIM PUTOM TIJEKOM IZVOĐENJA LAPAROSKOPSKE KOLECISTEKTOMIJE – USPOREDNA ANALIZA

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Ova studija je imala za cilj pružiti usporedbeni prikaz primjene supraglotičnih uređaja (laringealne maske Supreme i i-gel) s endotrahealnom intubacijom u kontroli dišnih putova, učinkovitosti ventilacije i oksigenacije tijekom izvođenja kirurških laparoskopskih operacija. Istraživanje je obuhvatilo 325 bolesnika, ASA klasifikacije I.-II. U prvoj skupini (115 bolesnika) dišni sustav je bio opskrbljen endotrahealnom intubacijom. U drugoj skupini (103 bolesnika) primijenjena je laringealna maska tipa Supreme, dok je maska i-gel korištena za kontrolu dišnih putova u trećoj ispitivanoj skupini (107 bolesnika). Promatrani parametri zabilježeni su i uspoređeni primjenom t-testa, ANOVA testa, Tukeyjeva testa i χ^2-testa. Tijekom praćenja zabilježeno je vrijeme postavljanja, broj pokušaja, orofaringealnog tlaka zaptivanja itd. Vrijeme postavljanja bilo je najduže u prvoj (14,7±1,65s), zatim u drugoj (15,5±1,05s) i najkraće u trećoj skupini bolesnika (14,1±1,27s). Usporedba testom ANOVA pokazala je statistički značajnu razliku (p<0,01). Izvedba postavljanja bila je gotovo jednaka u sve tri ispitane skupine (p=0,907, χ^2-test). Usporedba orofaringealnog tlaka zaptivanja između druge (35,95±2,92 cm H_2O) i treće skupine (36,47±1,43 cm H_2O) nije dala statističku značajnost (p=0,314, t-test). Endotrahealna cijev, laringealne maske Supreme i i-gel bile su podjednako učinkoviti uređaji za upravljanje dišnim putovima u laparoskopskim intervencijama. Omogućuju učinkovitu ventilaciju i oksigenaciju bez obzira na bilo kakve specifične patofiziološke promjene koje prate laparoskopsku kolecistektomiju.

Ključne riječi: *Endotrahealna cijev; Laringealna maska; Dišni put; Laparoskopska kolecistektomija*