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Relationship Between Respiratory Dynamics and Body Mass Index in Patients Undergoing General Anesthesia with Laryngeal Mask Airway (LMA) and Comparison Between Lithotomy and Supine Positions

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Data Interpretation D
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Background: This study aimed to compare respiratory dynamics in patients undergoing general anesthesia with a laryngeal mask airway (LMA) in lithotomy and supine positions and to validate the impact of operational position on effectiveness of LMA ventilation.

Material/Methods: A total of 90 patients (age range, 18–65 years) who underwent general anesthesia were selected and divided into supine position (SP group) and lithotomy position groups (LP group). Vital signs and respiratory dynamic parameters of the 2 groups were measured at different time points and after implantation of an LMA. The arterial blood gas was monitored at 15 min after induction. The intraoperative changes of hemodynamic indexes and postoperative adverse reactions of LMA were recorded. The possible correlation between body mass index (BMI) and respiratory dynamic indexes was analyzed.

Results: With prolonged duration of the operation, the inspiratory plateau pressure (Pplat), inspiratory resistance (RI), and work of breathing (WOB) gradually increased, while chest-lung compliance (Compl) and partial pressure of carbon dioxide in end-expiratory gas ($P_{et}CO_2$) gradually decreased (all P value <0.05). The mean airway pressure (Pmean), Pplat, and expiratory resistance (Re) in the LP group were significantly higher than in the SP group (P<0.05), while the peak inspiratory flow (FImax), peak expiratory flow (FEmax), WOB, and Compl in the LP group were significantly lower than in the SP group (P<0.05). BMI was positively correlated with peak airway pressure (PIP/Ppeak), Pplat, and airway resistance (Raw) and was negatively correlated with Compl; the differences among patients in lithotomy position were more remarkable (P<0.05).

Conclusions: The inspiratory plateau pressure and airway resistance increased with prolonged duration of the operation, accompanied by decreased chest-lung compliance. Peak airway pressure and airway resistance were positively correlated with BMI, and chest-lung compliance was negatively correlated with BMI. Changes among patients in lithotomy position were more remarkable than those in supine position.

MeSH Keywords: **Body Mass Index • Laryngeal Masks • Lithotripsy • Supine Position • Ventilators, Mechanical**

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Background

Laryngeal mask airway (LMA) is characterized by simple operation, a small airway, and cardiovascular reactions, and is favored in clinical anesthesia, even sometimes for obese patients [1]. However, LMA as a relatively unstable artificial airway and may induce hypoventilation, upper airway obstruction, gastroesophageal reflux and aspiration, and other abnormalities, even with accurate positioning. These abnormalities are more likely to appear in the presence of abnormal respiratory dynamic parameters, such as high airway resistance or poor chest-lung compliance, caused by various factors. The main factors affecting respiratory dynamic parameters include individual physiological and pathological factors such as, age, body mass index (BMI), respiratory system diseases, and anesthesia-related factors such as surgical method, surgical position, ventilation mode, and ventilation tools [2–6].

With increased BMI, pulmonary compliance decreases due to excessive adipose tissue, leading to restrictive changes of lung functions, such as decreased vital capacity, functional residual capacity, expiratory reserve volume and inspiratory capacity, forced expiratory volume in 1 second (FEV_1), and diffusion capacity for carbon monoxide of the lung [2,3]. In the surgical process, any position that compresses or limits thoracic activity or diaphragmatic contraction and leads to reduced thorax-lung compliance may also affect pulmonary ventilation [5]. These factors limit the use of LMA in overweight patients with specific surgical positioning.

Therefore, this study aimed to compare the differences in respiratory dynamic indexes in patients with LMA ventilation in supine and lithotomy surgical positions, and also to observe the correlation between BMI and respiratory dynamic indexes with these 2 positions, to provide evidence for secure implementation of LMA in overweight patients with specific surgical positions.

Material and Methods

This study was approved by the Ethics Committee of Shanghai General Hospital Affiliated to Shanghai Jiaotong University. Informed consent was obtained from all patients or their family members. Patients undergoing elective surgery in orthopedics and urology between July and November 2013 were selected. Inclusion criteria were: patients were Grade I or II according to American Society of Anesthesiologists (ASA) marking system, and aged 20–65 years old. Patients were divided into a supine position group (SP group) and a lithotomy position group (LP group) according to the surgical positions. The sample size was calculated based on pilot experiments, with a calculation formula: $n=(Z\alpha/2)^2\sigma^2/E^2$, 95% confidence interval. Exclusion criteria were: significant abnormalities in liver, kidney, heart, or lung functions, history of gastroesophageal reflux, or respiratory tract infection within the previous 3 weeks.

Patients fasted for 8 h prior to surgery, and were given an intravenous supplement of 500 mL 5% glucose if necessary. Electrocardiogram, heart rate (HR), non-invasive blood pressure (NIBP), pulse oxygen saturation (SpO_2), and respiratory dynamic indexes were continuously monitored using a multifunction monitor (Datex-Ohmeda S/5 AM, GE Company, CT).

Prior to the induction of general anesthesia, patients received intravenous infusion of 10 mL/kg sodium lactate Ringer's solution. The HR, NIBP, and SpO_2 were recorded. Anesthesia induction was followed after preoxygenation of the lungs through a facemask. Patients received intravenous injection of midazolam 1~2 mg, fentanyl 2~4 μg/kg, and propofol 1.5~2.0 mg/kg. After the patients lost consciousness, they were given an intravenous injection of succinylcholine 1~2 mg/kg, and an LMA (traditional type, Tuoren Co., China) of appropriate size ($3^{\#}$~$5^{\#}$) was implanted 1 min later. Intravenous injection of rocuronium 0.2~0.4 mg/kg was given after the LMA was positioned. After implantation of the LMA, patients were given mechanical ventilation using volume-controlled mode (Datex-Omeda Aespire, GE) until the end of surgery. The inspiration: expiration ratio was set at 1:1.5, the tidal volume was 6~10 mL/kg, positive end-expiratory pressure was set at zero, and the partial pressure of carbon dioxide in end-expiratory gas ($p_{et}CO_2$) was maintained at 35~40 mmHg. The air capsule of the LMA was inflated with 20~30 ml of air, during which the chest fluctuations were observed and breath sounds in the lungs and neck were auscultated to identify the position of the LMA. Finally, examination using fiberoptic bronchoscopy was performed to identify the position of the glottidis rimae and to exclude airway obstruction. The LMA position was scored using the marking system described by Brimacombe [7], and then the test of airway sealing pressure was performed. Cases with disqualifying scores or test results were switched to endotracheal intubation and were excluded from the study.

Prior to skin incision, patients received intravenous injection of fentanyl 0.05~0.10 mg and sevoflurane was inhaled continuously with a volume fraction of 1~4% in 100% oxygen in 1 L/min fresh airflow during the operation. The inhalational concentration was maintained at about 1.0 MAC, and additional intravenous injection of fentanyl 1~2 μg/kg was administered when the elevations of HR and NIBP were greater than 20% of their baseline amounts.

Patients with systolic pressure <90 mmHg or with a reduction of mean arterial pressure (MAP) of 30% were given an intravenous injection of ephedrine at a dose of 3~6 mg/time and patients with HR<50 beats/min received intravenous injection of

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atropine 0.2~0.5 mg/time. Patients who showed resistance to the ventilator during the operation were given an additional injection of intravenous rocuronium with a dose of 10 mg/time.

The main outcome measures were: respiratory dynamic parameters, including inspiratory plateau pressure (Pplat), mean airway pressure (Pmean), peak airway pressure (PIP/Ppeak), positive end-expiratory pressure (PEEP), peak inspiratory flow (FImax), peak expiratory flow (FEmax), airway resistance (Raw), and partial pressure of carbon dioxide in end-expiratory gas ($P_{et}CO_2$). These were recorded prior to receiving anesthesia induction (T_0) and at 1 (T_1), 5 (T_2), 10 (T_3), 15 (T_4), 30 (T_5), and 45 (T_6) min after implantation of LMA. Arterial blood gas was monitored at 15 min after anesthesia induction (i-STAT blood gas monitor, Abbott Company), including arterial partial pressure of carbon dioxide ($PaCO_2$) and arterial partial pressure of oxygen (PaO_2). Physiologic dead space in percent of tidal volume (V_D/V_T), static compliance (Cst), expiratory resistance (Re), and work of breathing (WOB) were calculated using the formula provided by Casati et al. [8]. Secondary outcome measures were: HR, NIBP, and SpO_2 at 1 (T_1), 5 (T_2), 10 (T_3), 15 (T_4), 30 (T_5), and 45 (T_6) min and at 5 min after retraction of the LMA (T_7). Air leakage of the LMA, aspiration, bucking during the operation, pharyngeal pain, trachyphonia, and muscular soreness after the operation and other adverse events were observed. Because the surgical position cannot be set with blind method, all the respiratory dynamic and hemodynamic indexes were objective data; therefore, all the intraoperative observation indexes were non-blind, and patients were followed up after the operation.

Statistical analysis

Statistical analyses were performed using SPSS 19.0 software (IBM Corp., NY). Measurement data are expressed as mean ± standard deviation (x±s). Testing of normality was performed using Shapiro-Wilk method. Parameters in line with normal distribution were performed using variance analysis. For repeated measurement data accorded with spherical symmetry assumption using variance analysis, the non-corrected F critical value was used. For data that did not accord with spherical symmetry assumption, the correction results using Greenhouse-Geisser method were used. Pairwise comparisons were performed using the LSD method. The parameters with non-normal distribution were tested using Mann-Whitney U or Kruskal-Wallis H methods. Count data were tested using Fisher exact probability. Comparisons of ranked data were performed using rank-sum test and P<0.05 was considered statistically significant. The logistic regression model was performed using linear regression analysis.

Results

For the pilot experimental study, the expected sample size was 23 cases in each group, which was satisfied because there were 49 and 41 cases in the SP and LP groups, respectively, who met the inclusion criteria for this study. In the SP group, there were 40 males and 9 females, with a mean age of 43.91±17.54 years old, and mean BMI of 23.9±3.1 kg/m^2. In the LP group, there were 23 males and 18 females, with a mean age of 49.63±15.5 years old, and a mean BMI of (24.3±3.8) kg/m^2. The differences between the 2 groups were not statistically significant (P>0.05). The SP group received intravenous infusion of propofol (1.70±0.40) mg/kg, fentanyl (4.60±1.00) μg/kg, and rocuronium (0.39±0.06) mg/kg and the LP group received intravenous infusion of propofol (1.60±0.50) mg/kg, fentanyl (4.20±0.90) μg/kg, and rocuronium (0.42±0.05) mg/kg. The difference in anesthetic drugs between the 2 groups was not statistically significant (P>0.05).

The heart rate, mean arterial pressure, and SpO_2 in the baseline were not significantly different between the 2 groups. During the surgery, the hemodynamic changes at different time points showed statistically significant differences within the same group. The heart rate and mean arterial pressure at different time points were not significantly different between the 2 groups. SpO_2 was maintained above 98% in all patients (Table 1).

In the SP group, with prolonged surgical duration, the Pplat, Pmean, PIP, and Raw were significantly elevated at T_5 compared with those at T_1 (P<0.05), and $p_{et}CO_2$ and Compl were gradually decreased (P<0.05), while the peak inspiratory pressure (PIP), mean airway pressure, peak inspiratory flow, peak expiratory flow, Vd/Vt and Re did not display significant differences at each time point during the operation (P>0.05). In the LP group, FImax, FEmax, and Re at time point T_5 were significantly increased (P<0.05) compared to T_1, and $p_{et}CO_2$, Compl, and WOB were significantly reduced (P<0.05). Airway pressure and Vd/Vt did not show significant differences at any time point during the operation (P>0.05). The indexes that showed significant changes are presented in Figure 1.

Pmean, Pplat, and Raw from time point T_1 to T_6 in the LP group were significantly higher than those at the corresponding time points in the SP group (P<0.05). FImax, FEmax, WOB, and Compl from time point T_1 to T_6 in the LP group were significantly lower than those at the corresponding time points in the SP group (P<0.05). At time point T_1, PIP was significantly higher in the LP group than in the SP group (P<0.05). At T_3, the $p_{et}CO_2$ in the LP group was significantly lower than that in the SP group (P<0.05). Vd/Vt at T_4 in the LP group was significantly higher than that in the SP group (*P*<0.05). p_aO_2 was not significantly different between the 2 groups (P>0.05).

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Table 1. Changes of hemodynamics indexes in the two groups (n_1=40, n_2=40, mean ±sd).

Time point	HR (beats/min)			MAP (mmHg)		
	SP group	LP group	p value	SP group	LP group	p value
Before induction	73.0±9.68	67.9±10.9	0.002	95.8±9.9	73.4±15.1	0.06
1 min after LMA implatation	73.4±9.7*	63.9±8.4	0.000	85.8±14.5	86.7±12.2*	0.398
5 min after LMA implatation	72.1±13.08	61.6±8.4	0.000	78.1±10.6*	78.3±11.9*	0.992
10 min after LMA implatation	69.9±10.8*	61.6±8.7*	0.000	78.3±13.3*	74.6±10.4*	0.096
15 min after LMA implatation	69.0±12.9*	63.9±6.73*	0.000	83.2±14.6*	74.8±12.2*	0.008
30 min after LMA implatation	69.7±12.0*	65.1±8.9	0.000	82.5±24.8*	79.7±13.5*	0.495
60 min after LMA implatation	71.4±8.2	66.9±11.7	0.092	60.0±24.6*	72.3±11.6*	0.089
5 min after retraction of LMA	78.2±14.0	77.8±14.1	0.006	99.8±10.7*	103.6±12.1	0.217

Data were presented as mean ±sd; * Compared with that before LMA implantation *P*<0.05. HR – heart rate; MAP – mean arterial pressure; SP group – supine position LP group – lithotomy position groups.

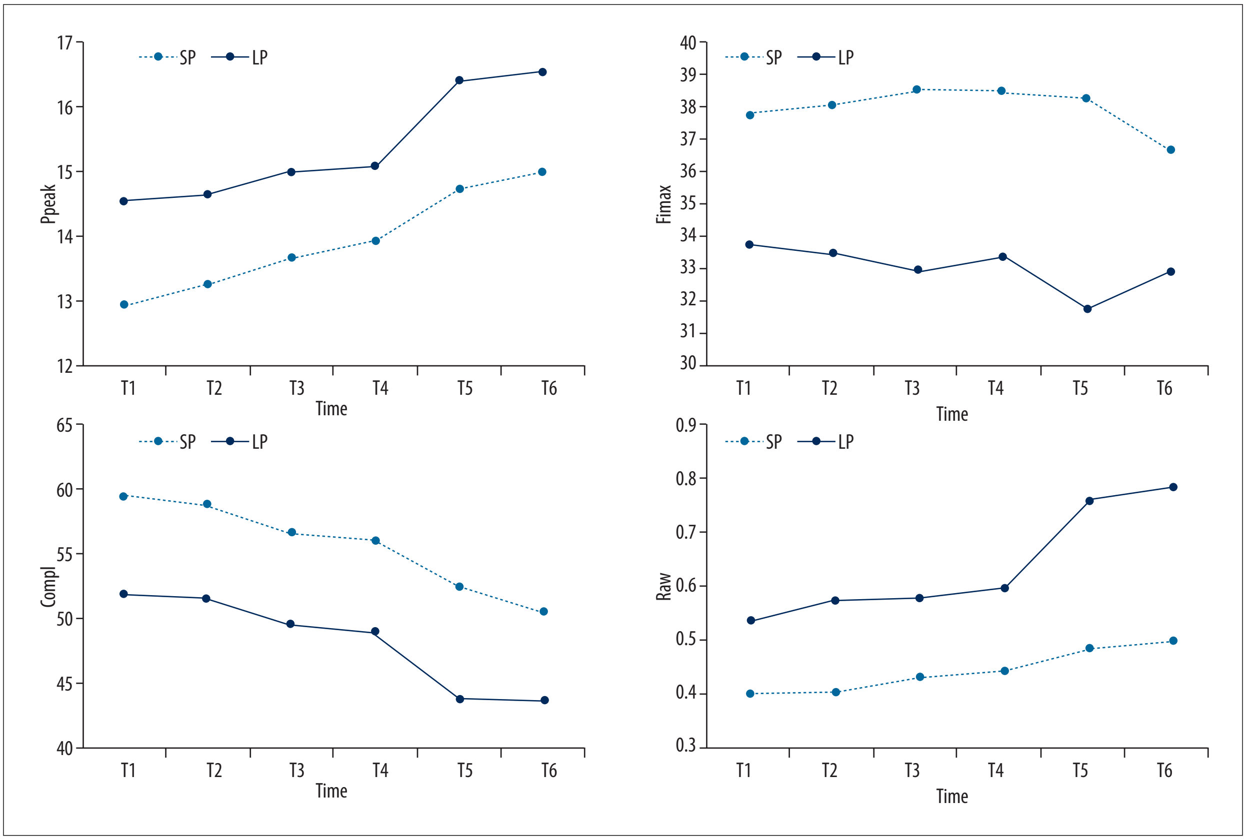

Figure 1. The changes of Ppeak, Fimax, Compl, and Raw at each time point, P<0.05 T_5 *vs.* T_1. Ppeak – means peak airway pressure; Fimax – means the peak inspiratory flow; Compl – means chest-lung compliance; Raw – means airway resistance.

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Table 2. Changes of respiratory dynamics indexes in the two groups (n=60, mean ±sd).

Index		1 min	5 min	10 min	15 min	30 min	45 min	60 min
PIP (cmH_2O)	SP	13.0±2.9	13.3±2.9#	13.7±2.9#	13.9±3.0#	14.7±3.5#	15.0±3.2#	15.8±3.5#
	LP	14.6±3.8*	14.7±3.7*	15.0±4.1*	15.1±4.1	16.4±5.1#	16.6±5.2#	14.8±3.1
Pmean (cmH_2O)	SP	4.0±1.1	4.1±1.1	4.2±1.1	4.2±1.1	4.5±1.1#	4.4±0.9#	4.7±0.9#
	LP	5.9±2.0*	5.8±1.7*	6.0±2.0*	6.0±2.1*	6.9±3.1*,#	7.2±3.4*	5.5±0.6
Pplateau (cmH_2O)	SP	10.7±2.5	10.6±2.8	11.3±2.5#	11.6±2.6#	12.2±2.9#	12.3±2.3#	13.1±2.4#
	LP	12.9±3.2*	12.9±3.3*	13.0±3.3*	13.3±3.3*	14.6±4.4*,#	14.7±4.7*,#	13.0±3.2
FImax ($L \cdot min^{-1}$)	SP	37.8±4.7	38.0±5.3	38.5±5.3	38.5±4.9	38.2±5.0	37.6±4.9	38.0±5.3#
	LP	33.8±3.9*	33.4±4.2*	32.9±4.4*,#	33.4±4.8*	31.7±5.2*,#	32.9±5.1*	32.4±5.7
FEmax (L·min–1)	SP	24.8±4.8	24.8±4.3	24.8±4.3	24.9±4.4	24.2±4.6	24.6±5.0	24.1±4.4
	LP	20.4±4.4*	19.6±4.2*	19.4±3.9*,#	19.5±4.1*,#	17.6±4.3*,#	18.0±5.5*,#	19.4±3.1
Compl ($ml \cdot cmH_2O^{-1}$)	SP	59.6±10.2	58.8±10.9	56.7±11.5#	55.1±12.2#	52.4±13.4#	51.1±11.6#	46.9±10.6#
	LP	51.9±12.8*	51.7±12.5*	49.5±12.9*,#	49.0±12.0*,#	43.8±13.1*,#	44.1±12.9*,#	51.5±6.1#
V_D/V_T	SP				0.16±0.004			
	LP				0.21±0.01*			
$EtCO_2$ (mmHg)	SP	38.7±4.1	36.0±3.7#	35.1±3.0#	34.2±3.0#	33.6±2.9#	34.1±3.4#	35.8±3.0#
	LP	37.0±4.3	34.6±3.6*,#	33.6±3.2#	33.4±3.5#	33.5±2.8#	34.0±3.1#	33.5±1.3*
$PaCO_2$ (mmHg)	SP				40.7±3.3			
	LP				41.4±3.8			
PaO_2 (mmHg)	SP				488.7±120.0			
	LP				465.5±130.5			
Raw ($cmH_2O \cdot l \cdot s^{-1}$)	SP	9.6±2.9	10.2±3.6#	10.1±3.5#	10.4±4.0#	10.8±3.6#	11.4±4.2#	11.7±3.6#
	LP	11.2±4.8*	10.5±4.3	10.9±4.8	11.1±4.9	11.9±7.2	12.8±7.5	10.8±3.1
Re ($cmH_2O \cdot l \cdot s^{-1}$)	SP	24.2±1.1	24.4±1.0	26.2±0.9#	26.8±1.0	29.2±1.3#	30.2±1.3#	35.0±1.4
	LP	32.34±2.0*	34.5±2.6*,#	34.68±3.1*	35.9±2.9*	45.5±8.1*,#	47.0±11.7*,#	52.4±3.0*,#
WOB (J)	SP	660.7±54.2	651.9±55.2	648.6±57.0	646.3±59.8	643.0±63.5	630.6±61.4#	625.0±67.0#
	LP	605.5±68.4*	603.5±65.4*	596.0±60.1*	584.5±57.8*,#	573.5±57.8*	586.2±57.6*	577.2±54.3#

Data were presented as mean ±sd; * Compared with SP group($P<0.05$); # Compared with that at 1 min after induction ($P<0.05$). PIP – peak airway pressure; Pmean – mean airway pressure; Pplat – inspiratory plateau pressure; FImax – peak inspiratory flow; FEmax – peak expiratory flow; Compl – chest-lung compliance; V_D/V_T – physiologic dead space in percent of tidal volume; $EtCO_2$ – end-tidal CO_2; $PaCO_2$ – arterial partial pressure of carbon dioxide; PaO_2 – arterial partial pressure of oxygen Raw: airway resistance; Re – expiratory resistance; WOB – work of breathing.

Time point T_5 displayed the largest difference of respiratory dynamic parameters and was selected for further analysis of the correlation between respiratory dynamic parameters and BMI (Table 2). At time point T_5, the Ppeak, Pplat, and Raw in the 2 positions were both positively correlated with BMI, and Compl was negatively correlated with BMI. It seems that the changes in the LP group were larger than those in the SP group, while the statistical analysis showed that only the changes in Raw were significantly different (Figure 2, $P<0.05$). When the risk of leakage of the LMA and gastro-esophageal reflux were set at a condition in which the Raw was higher than 25 cm-H_2O, the final logistic regression model demonstrated the corresponding critical value of BMI to be 34.2 in the LP group and 44.7 in the SP group (Figure 3).

In the SP group, bucking and pharyngalgia occurred in 4 and 2 cases, respectively, and in the LP group, bucking and pharyngalgia occurred in 5 and 2 cases, respectively. No patients in the 2 groups had gastroesophageal reflux, aspiration, myalgia, trachyphonia, or other adverse events.

Discussion

LMA as a supraglottic airway tool has been widely used in clinical anesthesia practice, mainly due to its advantages, including minimal airway irritation, stable hemodynamics, fast postoperative recovery, and fewer airway complications. Biedler et al. compared leakage pressure and peak airway pressure with

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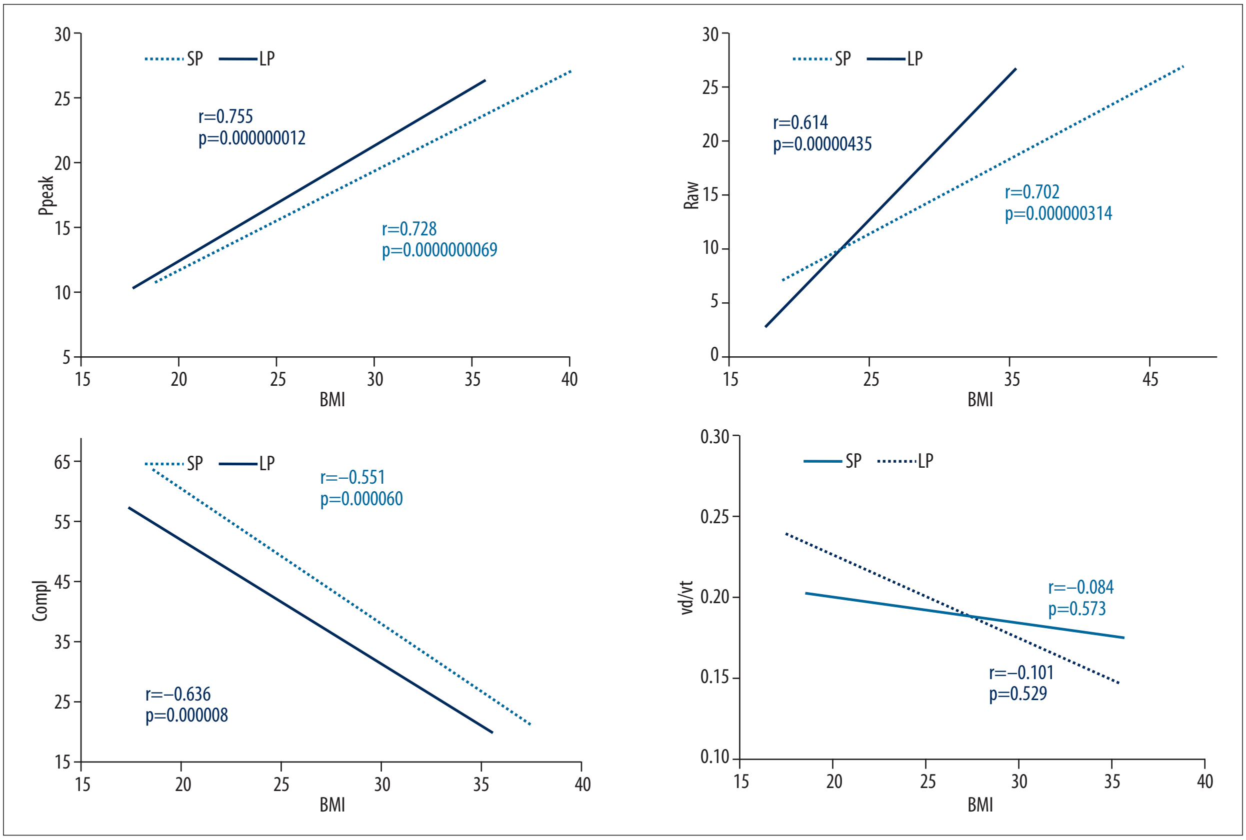

Figure 2. Correlation between Ppeak, Raw, Compl, Vd/Vt, and BMI: Ppeak, Pplat and Raw in the 2 positions were both positively correlated with BMI and Compl was negatively correlated with BMI; P>0.05 for Ppeak, Compl and Vd/Vt, P<0.05 for Raw, when LP *vs.* SP. Ppeak means peak airway pressure; Raw means airway resistance; Compl means chest-lung compliance; Vd/Vt means physiologic dead space in percent of tidal volume (V_D/V_T); BMI – body mass index; LP – lithotomy position group; SP – supine position group.

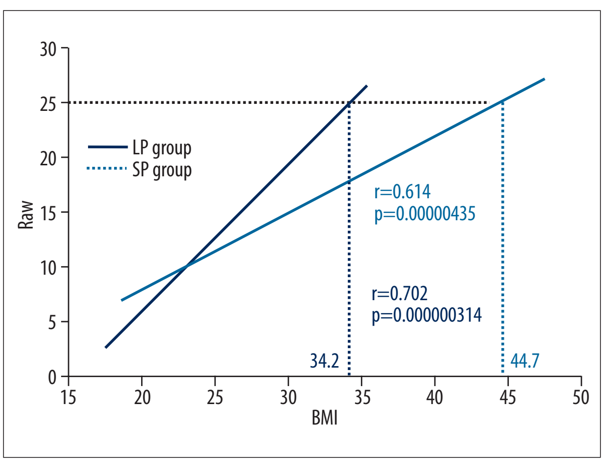

Figure 3. The logistic regression model for the corresponding critical value of BMI in the 2 groups. Raw – means airway resistance; BMI – body mass index; SP – supine position group; LP – lithotomy position group.

laryngeal tube and classical LMA in surgery with different head and neck angles, and found that the leakage pressure and peak airway pressure with LMA at different positions were lower than those obtained with laryngeal tube, suggesting that the LMA has good airway sealing and achieves good ventilation effect [9]. However, some researchers have found that about 10% of patients using LMA have leakage with an airway pressure >25 cmH_2O [10,11], thus creating concerns about hypoventilation, gastroesophageal reflux, and aspiration in using LMA when there are changes in respiratory dynamics (such as high airway resistance and attenuated chest-lung compliance). The present study aimed to determine whether surgical position and body weight lead to hypoventilation or gastroesophageal reflux by affecting respiratory dynamics.

According to previous reports, positions causing hypoventilation, from severe to mild, are: deep flexibility position, head flexion lithotomy position, prone position, lateral position, and high position with gallbladder pad or kidney pad. Lithotomy position is prone to movement of the pelvis and abdominal organs towards the head, as well as decreasing space for lung activity by knee lift to elevate the sacrum, thereby creating relatively shorter lumbar vertebra height, decreasing lung compliance

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and increasing airway resistance [5]. Therefore, we needed to correct tidal volume through increasing airway pressure, while the work of breathing was also increased. Therefore, in LMA ventilation with a lithotomy position, a high airway pressure may be needed to ensure tidal volume, even though it may increase LMA leakage and thus increase the risk of gastroesophageal reflux. We wondered whether an unstable airway, such as in use of LMA, will lead to hypoventilation when chest-lung compliance is affected by lithotomy position. This study compared changes in respiratory dynamics parameters in patients undergoing general anesthesia with LMA in lithotomy and supine positions. Our results showed that with these 2 positions, the inspiratory plateau pressure, inspiratory resistance, and work of breathing increased with prolonged duration of the operation, and the elevation of inspiratory plateau pressure in the LP group was significantly greater than that in the SP group. In the 2 positions, Cdyn and Cst decreased with prolonged duration, and the decrease in the LP group was significantly greater than in the SP group. Results at time point T_7 showed a different trend from those at the other time points. Surgery ended in many patients in the 2 groups at T_7, and the statistical results were unreliable due to insufficient sample size. The variation tendency of respiratory dynamics in this study was consistent with previous reports in patients undergoing general anesthesia with endotracheal catheter in Trendelenburg position, head flexion lithotomy position, and prone position [4–6]. However, these respiratory dynamic changes presented a higher clinical risk in LMA ventilation than in ventilation with endotracheal intubation. In addition, our results showed that the peak inspiratory flow and peak expiratory flow in the LP group were lower than in the SP group, which we suspect was induced by the changes in Ri and Re.

Obesity is thought to be a risk factor for hypoventilation [12]. Soto et al. found that the airway resistance and peak airway pressure were significantly increased and the chest-lung compliance was remarkably decreased in 24 very obese patients undergoing laparoscopic bariatric surgery under general anesthesia using endotracheal intubation [13], but the report was focused on a very obese population. Another study involving 232 obese patients (BMI >30 kg/m^2) found that, compared with endotracheal intubation, although the LMA presents an increased risk of leakage, the ventilation outcome was not affected, and it may reduce the bucking at the end of anesthesia, shows faster emergence from anesthesia, and significantly reduces the incidence of postoperative hypoxemia [1]. The present study found that the peak airway pressure, airway plateau pressure, and airway resistance in the 2 positions were positively correlated with BMI, while the dynamic and static compliances were negatively correlated with BMI, which was similar to the results in obese patients obtained by Soto [13]. However, we provided more comprehensive data on respiratory dynamics, and did not limit the study to obese subjects. The normal value of BMI is 18.5–24.9 kg/m^2, while a BMI value of 25–28 kg/m^2 is overweight, and >30 kg/m^2 is considered obese. The mean BMI was 23.9±3.0 in the supine position group and 24.0±2.6 kg/m^2 in the lithotomy position group. Therefore, our results suggest the need to consider the changes in respiratory dynamics due to weight gain and the effect on ventilation, even in subjects with normal BMI. Given the specificity of LMA ventilation, such as hypoventilation and risk of gastroesophageal reflux and aspiration, the results of this study have greater clinical value than the results obtained in endotracheal intubation by Soto. Although we failed to show changes in respiratory dynamics that might change the ventilation effect, our results indicate that LMA ventilation should be done cautiously in patients with BMI ≥34.2 in lithotomy position or BMI ≥44.7 in supine position, to avoid complications due to excessive airway resistance, as shown in Figure 3.

Hypoventilation caused by surgical position and obesity has already been reported in the literature, but our study focused on the correlation between respiratory dynamics and BMI in 2 different surgical positions. We found the point at which a BMI value indicates risk of hypoventilation or gastroesophageal reflux due to exceeding airway resistance.

The incidence of atelectasis at rest in obese patients was 2 times higher than in non-obese patients [3] and is generally believed to be caused by residual gas and ineffective ventilation in blood flow due to increased closing capacity. Intrapulmonary shunt may aggravate hypoxemia, especially when the patients are in supine position, since the abdominal wall and abdominal contents may exert pressure on the diaphragm [5]. Gaszynski conducted a study in 47 obese patients (BMI 49.54±7.21 kg/m^2) and found that overweight patients (BMI >60 kg/m^2) have significantly lower preoperative lung functions and significantly higher postoperative hypoxemia [14]. In the present study, no patients had postoperative hypoxemia, which could be because the BMI of our patients was close to normal, and patients with preoperative pulmonary dysfunctions were excluded. This is also a limitation of the present study, and further studies are needed in obese populations.

In this study aspiration did not occur in either of the groups, and other complications, such as bucking and pharyngalgia, rarely occurred. The differences between the 2 groups were not statistically significant, which is consistent with previous results [6]. However, further studies are required to validate whether this is associated with the small sample size.

Conclusions

The airway pressure and airway resistance increased with prolonged operation time in patients undergoing general

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anesthesia with classical LMA, and it was more significant in lithotomy position than in supine position, accompanied by decreased chest-lung compliance. The peak airway pressure and airway resistance were positively correlated with BMI, and chest-lung compliance was negatively correlated with BMI. The changes among patients in lithotomy position were even more remarkable than those in supine position. The critical value of BMI was 34.2 in lithotomy position and 44.7 in supine position, corresponding to the risk of airway resistance of 25 cmH_2O. Therefore, one should be cautious while using LMA in overweight patients with BMI ≥34.2 in lithotomy position.

Conflicts of interest statement

The authors have no conflicts of interest to declare.

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