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SCIENTIFIC ARTICLE

Impact of Grade I obesity on respiratory mechanics during video laparoscopic surgery: prospective longitudinal study

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KEYWORDS
Respiratory mechanics;
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Abstract
Introduction and objectives: The association pneumoperitoneum and obesity in video laparoscopy can contribute to pulmonary complications, but has not been well defined in specific groups of obese individuals. We assessed the effects of pneumoperitoneum in respiratory mechanics in Grade I obese compared to non-obese.
Methods: Prospective study including 20 patients submitted to video laparoscopic cholecystectomy, normal spirometry, divided into non-obese (BMI $\leq 25\,kg.m^{-2}$) and obese (BMI > $30\,kg.mg^{-2}$), excluding Grade II and III obese. We measured pulmonary ventilation mechanics data before pneumoperitoneum (baseline), and five, fifteen and thirty minutes after peritoneal insufflation, and fifteen minutes after disinflation (final). *Results:* Mean BMI of non-obese was $22.72 \pm 1.43\,kg.m^{-2}$ and of the obese $31.78 \pm 1.09\,kg.m^{-2}$, $p < 0.01$. Duration of anesthesia and of peritoneal insufflation was similar between groups. Baseline pulmonary compliance (Crs) of the obese (38.3 ± 8.3 mL.cm H_2O^{-1}) was lower than of the non-obese (47.4 ± 5.7 mL.cm H_2O^{-1}), $p = 0.01$. After insufflation, Crs decreased in both groups and remained even lower in the obese at all moments assessed (GLM $p < 0.01$). Respiratory system peak pressure and plateau pressure were higher in the obese, albeit variations were similar at moments analyzed (GLM $p > 0.05$). The same occurred with elastic pressure, higher in the obese at all times (GLM $p = 0.04$), and resistive pressure showed differences in variations between groups during pneumoperitoneum (GLM $p = 0,05$).

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Conclusions: Grade I obese presented more changes in pulmonary mechanics than the non-obese during video laparoscopies and the fact requires mechanical ventilation-related care.
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PALAVRAS-CHAVE
Mecânica respiratória;
Obesos;
Videolaparoscopia;
Ventilação;
Complacência

Impacto da obesidade Grau I na mecânica respiratória durante cirurgia videolaparoscópica: estudo longitudinal prospectivo

Resumo

Justificativa e objetivos: Em videolaparoscopias, a associação de pneumoperitônio e obesidade pode contribuir para complicações pulmonares, mas não está bem definida em grupos específicos de obesos. Avaliamos os efeitos do pneumoperitônio na mecânica respiratória dos obesos Grau I em comparação aos não obesos.
Métodos: Estudo prospectivo envolvendo 20 pacientes submetidos à colecistectomia videolaparoscópica, com espirometria normal, separados em não-obesos (IMC $\leq$ 25 kg.m^{-2}) e obesos (IMC > 30 kg.mg^{-2}, excluídos obesos Grau II e III. Mensuramos dados da mecânica ventilatória pulmonar antes do pneumoperitônio basal, após cinco, quinze e trinta minutos da insuflação peritoneal e quinze minutos após a desinsuflação final. Resultados: O IMC médio dos não obesos foi de 22,72 $\pm$ 1,43 kg.m^{-2} e dos obesos 31,78 $\pm$ 1,09 kg.m^{-2}, $p <$ 0,01. A duração da anestesia e da insuflação peritoneal foram semelhantes entre os grupos. A complacência pulmonar (Crs) basal dos obesos (38,3 $\pm$ 8,3 mL.cm H_2O^{-1}) foi inferior aos não obesos (47,4 $\pm$ 5,7 mL.cm H_2O^{-1}), $p =$ 0,01. Após a insuflação, a Crs diminuiu nos dois grupos e permaneceu ainda mais baixa nos obesos em todos os momentos avaliados (GLM $p <$ 0,01). A pressão de pico e a pressão de platô do sistema respiratório foram mais elevadas nos obesos, mas apresentaram semelhantes variações nos momentos analisados (GLM $p >$ 0,05). O mesmo ocorreu com a pressão elástica, mais elevada nos obesos em todos tempos (GLM $p =$ 0,04), e a pressão resistiva apresentou diferenças nas variações entre os grupos durante o pneumoperitônio (GLM $p =$ 0,05).
Conclusão: Obesos Grau I apresentam maiores alterações na mecânica pulmonar que os não obesos em videolaparoscopias e este fato recomenda cuidados relacionados a ventilação mecânica.
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Introduction

According to the World Health Organization (WHO), obesity is defined by a Body Mass Index (BMI) $\geq$ 30 kg.m^{-2}. By and large, 13% of the global adult population was considered obese in 2014.[1]

The National Health and Nutrition Examination Survey (NHANES) established that 35% of adult men and 40.4% of adult women among 5,455 adults surveyed in the United States were obese.[2] Consequently, anesthesiologists are facing the unavoidable increasing challenge of providing better care to these patients, and appropriate mechanical ventilation can minimize any consequences to the respiratory system, reducing the incidence of postoperative complications and hospital length of stay.[3]

Increased body mass index and intra-abdominal pressure can lead to alveolar collapse.[4] Thus, atelectasis, decrease in functional residual capacity and changes in the ventilation/perfusion ratio contribute to a decrease in arterial oxygenation and are elements that require peritoneal insufflation during surgery, mostly in the obese.

These issues are actually more important in the obese, resulting in changes in pulmonary mechanics such as decreased compliance and increased airway pressures.[5,6] Therefore, acknowledging these problems can lead to better intraoperative management. Moreover, the effects of peritoneal insufflation on respiratory components in Grade I obese patients in low risk video laparoscopic surgeries, such as cholecystectomies, are uncommon.

Our assumption, therefore, is that significant changes in pulmonary mechanics can occur even in a specific population during a short peritoneal insufflation period. The objective of the present study was to compare pulmonary respiratory mechanics in Grade I obese and non-obese patients submitted to laparoscopic cholecystectomy and general anesthesia. The secondary objective was simultaneous assessment of blood oxygenation exchange.

Methods

The study was prospective observational, approved by the Hospital Research and Ethics Committee and with Consent Forms signed by participants.

Only Grade I obese were included to reflect a more prevalent group of the routine practice in our country, and Grades II and III obese patients, patients with chronic obstructive or restrictive lung disease or heart disease were excluded. We studied non-obese and Grade I obese women submitted to video laparoscopic cholecystectomy according to Body Mass Index (BMI), aiming at perfectly uniform groups: Group 1 (BMI $\leq$ 25 $Kg.m^{-2}$) and Group 2 (> 30 $Kg.m^{-2}$), previous normal spirometry (COLLINS – Collins Medical Inc. Braintree, MA), Morris pattern.

All patients were submitted to general anesthesia and intravenous induction, preceded by 100% oxygen facial mask for three minutes. For tracheal intubation with a cuffed tracheal tube number 7.5, the combination of 2–2.5 $mg.Kg^{-1}$ of propofol with 5 $mcg.Kg^{-1}$ of fentanyl and 1.0 $mg.Kg^{-1}$ of succinylcholine was used.

Following, intermittent atracurium and continuous infusion propofol were used, before the beginning of the pneumoperitoneum, and at the final 15 minutes without pneumoperitoneum. Arterial blood for blood gases, hematocrit and hemoglobin was collected. Patients were placed on volume controlled mechanical ventilation mode (Cicero-Dräger, Lübeck, Germany) using a circular system with reabsorption of CO_2. Respiratory parameters were set to respiratory rate (14 cpm), inspiration/expiration ratio (1:2) and tidal volume (6–8 $mg.Kg^{-1}$ of ideal weight) to keep $ETCO_2$ below 40 mmHg, and minimal positive end-expiration pressure.

Oxygen-air gas mixture ($FiO_2 = 0.50$) was administered. Airway pressure, flow and esophageal pressure data were acquired at 10% and 60% second inspiratory pause times. The gas analyzer was connected to the ventilator and equipment was previously calibrated.

Pneumoperitoneum with CO_2 was attained using an automatic insufflator (Stryker Endoscopy 30 L High Flow Insufflator, Santa Clara, CA, US). Intra-abdominal pressure was limited to 15 mmHg.

Airway pressure and inspiratory and expiratory flows were measured by a variable orifice pneumotachograph (Bicore CP-100 respiratory monitor, Irvine, CA, US) (FAPESP process 95/05329-0). The sensor (Var-Flex® flow transducer, Allied Healthcare, CA, US) was inserted in the respiratory system between the proximal tip of the tracheal cannula and the Y piece.

Esophageal pressure was measured using an air-filled catheter (SmartCath Esophageal catheter, BEAR Medical Systems, Irvine, CA, US) inserted nasally, positioned in the distal third of the esophagus and confirmed by the occlusion test[7] and by observing return to spontaneous breathing after recovery from succinylcholine.

Esophageal and airway pressure signals were recorded during one minute, after which the changes in the $\Delta Pes/\Delta Paw$ ratio were measured. Variations around 1 (0.9–1.1) were accepted.

In order to measure plateau pressure, and then calculate compliances and dynamic resistances, we recorded flow, airway pressure and esophageal pressure signals for 60 seconds at five standard moments, with 10% and 60% inspiratory pause times: T0-baseline: before pneumoperitoneum; T5, T15, T30: at five, fifteen and thirty minutes during the pneumoperitoneum; and Tfinal: fifteen minutes after deflation of the pneumoperitoneum.

Signals acquired by the respiratory monitor (Bicore CP-100) were digitalized, and through the serial exit (RS-232), were transferred to a microcomputer that used the LabVIEW TM 5.1 program (National Instruments Corp, US) to build ''Virtual Instruments'' (VIs) for analysis, correction and digital handling of each variable. Tidal volumes were obtained through digital integration of the flow curve. The program then performed the final calculation by the multiple linear regression method, using the movement equation, as follows:

$PAW = EV + RV' + K$; where: PAW, Airway Pressure; V, Lung Volume; E, Elastance; V', Air flow; K, Final expiratory pressure; R, Resistance.

Thus, we obtained parameters such as: tidal volume, resistance and compliance and elastance. Breathing cycles with inspiratory pause or isolated breathing cycles were used to attain peak and plateau pressure of airways.

Sample size

In order to calculate the sample, an estimated difference between the means of measurements of pulmonary compliance of 10 $mL.cm^{-1}H_2O^{-1}$, and standard deviations determined for each group at 8 $mL.^{-1}$ cm H_2O^{-1} in an 1/1 inclusion ratio for groups were taken into account. At least ten patients per group were required by considering a Type I error (alpha, significance) of 0.05 and Type II error (Beta, 1- power) of 0.20.

Patients were allocated by stratification of similar features using the data combination regression method to determine inclusion, taking into account age, surgeon, anesthetist and previous diseases, if any. Thus, the number of participants in each group was exactly the same and groups were similar; moreover, only women and one kind of surgery were included for perfectly uniform data.

The physicians responsible for patient care did not take part in the study and were not aware of what data would be collected. Data were collected by a trained team that had no information of patients' weight and height. Results were analyzed by a statistical team that was only aware that data came from patients identified as either belonging to Group 1 or 2. Groups were defined after finishing all analyses.

Statistical analysis

All parameters were represented as means and medians, with respective standard-deviations and minimum and maximum values. Parameters obtained by spirometry, blood gases, hematimetric and ventilometry data were compared by *t* or Mann Whitney tests, depending on whether data were parametric or non-parametric. To analyze respiratory mechanic parameters, we used two factor (groups and time) analysis of variance, with repeated measurements of one factor – General Linear Model (GLM), and comparison of values of both groups at the several moments, using ANOVA with Bonferroni correction. The level of significance established was 5%, corrected by Bonferroni when the different moments were analyzed. The SPSS 25.0 program (SPSS Inc., US) was used.

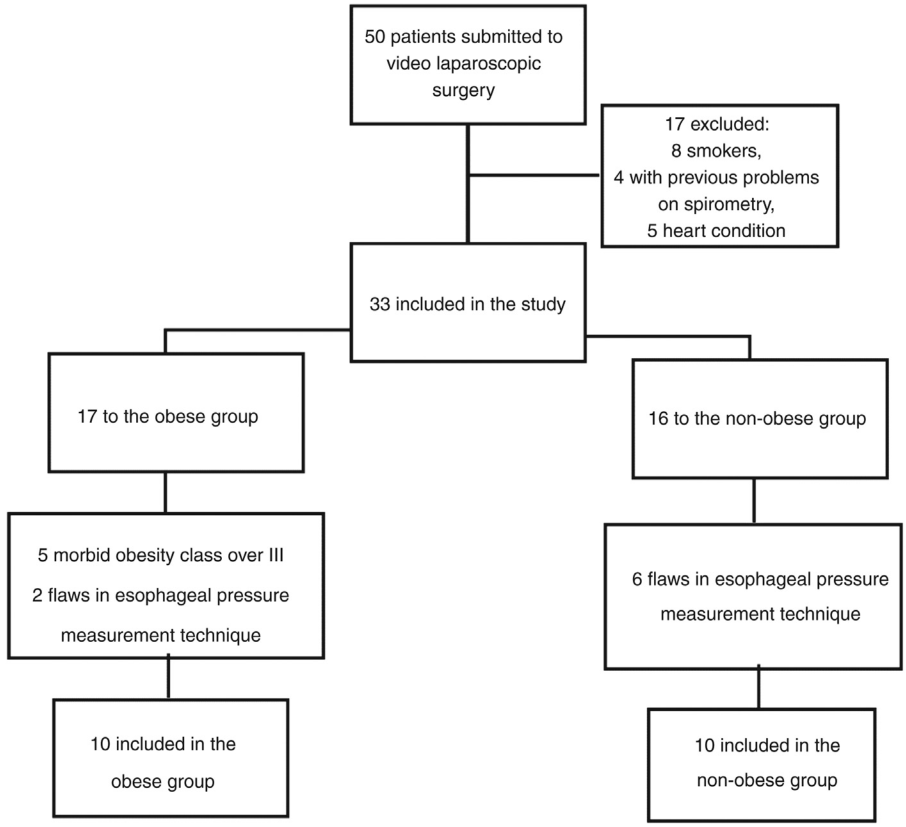

Figure 1 Patient inclusion flowchart.

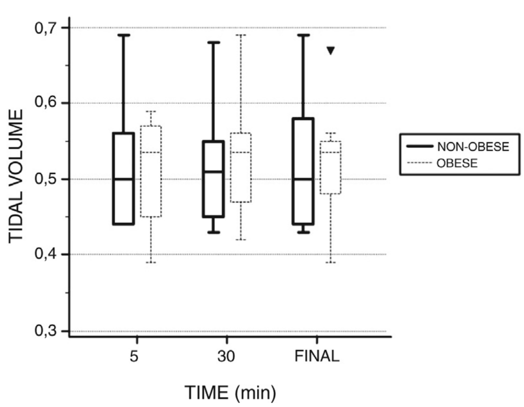

Figure 2 Comparison of tidal volumes of the obese and non-obese during surgery.

Results

Of the 50 patients admitted for the surgical procedure, 33 met inclusion criteria, although only 20 were included in the study. The remaining patients were excluded due to data acquisition flaws or because they were Grade II or III obese. Patients were assessed and classified as physical status ASA 1 or 2 (Fig. 1).

Patients' clinical characteristics and spirometry data are in Table 1. Both groups had similar baseline attributes, except for BMI, which was a group defining parameter.

Fig. 2 shows tidal volumes used before peritoneal insufflation, at 5 and 30 minutes, and after disinflation. Figures are medians and interquartile intervals of the two groups. There were no significant differences between groups.

Arterial gases during abdominal insufflation were similar between the groups with variations during insufflation, but there were no differences between groups.

Oxygenation and ventilation indices were calculated. Analysis of $PaCO_2/E_tCO_2$ (partial arterial carbon dioxide pressure and expired carbon dioxide fraction ratio) showed only an initial statistical difference between the groups studied, albeit not clinically relevant. PaO_2/FiO_2 (partial arterial oxygen pressure and inspired oxygen fraction ratio) decreased in both groups after peritoneal insufflation. The fall persisted until the end of the procedure, and was greater among the obese ($p \leq 0.001$) (Table 2).

Respiratory mechanic values calculated at five moments showed that, regarding respiratory system compliance (Crs), patients in the obese group had a lower Crs ($p = 0.012$). Baseline Crs of the obese was lower than of the non-obese group, 38.3±8.3 $mL.cm^{-1}H_2O^{-1}$ and 47.4 ± 5.7 $mL.cm^{-1}H_2O^{-1}$, respectively. Crs fell significantly during peritoneal insufflation ($p < 0.001$), and when 5, 15 and 30 minute measurements were compared to baseline Crs of the obese group, they were significantly lower ($p = 0.007$) (Fig. 3).

Respiratory system elastic pressure after inspiratory pause varied differently between groups. The obese group presented a significantly higher baseline respiratory system elastic pressure than the non-obese group ($p = 0.01$). During peritoneal insufflation, increase in respiratory system elas-

Table 1 Characteristics of patients included in the study, comparing non-obese and obese patients.

Characteristics	All patients(n = 20)	Non-obese(n = 10)	Obese (n = 10)	*p*-value
Age (years)	42.85 ± 16.5	39.1 ± 16.4	46.6 ± 16.6	0.32
Height (m)	1.54 ± 0.1	1.554 ± 0.1	1.526 ± 0.1	0.39
Weight (kg)	64.545 ± 14.0	54.59 ± 5.7	74.5 ± 12.7	0.00
BMI (kg.m-^{2})	27.186 ± 5.4	22.72 ± 1.43	31.78 ± 1.09	0.00
Duration of surgery (min)	115.4 ± 11.6	123.4 ± 21.6	106.0 ± 13.8	0.27
Duration of pneumoperitoneum (min)	62.4 ± 9.5	68.4 ± 9.7	59.3 ± 11.8	0.56
Spirometry data				
FVC (L)	3.241 ± 0.7	3.351 ± 0.6	3.119 ± 0.9	0.50
FVC (%)	104.84 ± 13.3	106.9 ± 12.3	102.56 ± 14.7	0.49
FEF1 (L)	2.794 ± 0.6	2.854 ± 0.4	2.728 ± 0.7	0.65
FEF1 (%)	118.32 ± 14.1	119 ± 16.7	117.56 ± 11.5	0.83
FEF1/ FVC (L)	86.79 ± 5.7	85.4 ± 4.9	88.33 ± 6.3	0.27
FEF1/ FVC (%)	113.53 ± 9.1	111.5 ± 8.9	115.78 ± 9.2	0.32
SVC (L)	3.364 ± 0.7	3.501 ± 0.6	3.212 ± 0.9	0.41
SVC (%)	111.95 ± 14.7	112.4 ± 16.4	111.5 ± 13.7	0.90

BMI, Body Mass Index; FVC, Forced Vital Capacity; FEF, Forced Expiratory Flow in 1 second; SVC, Slow Vital Capacity.

Table 2 Hematimetric and blood gas parameters of groups during surgery.

Characteristics	Non-obese(n = 10)	Obese(n = 10)	*p*-value
Hb (g.L^{-1})			
Initial	12.5 ± 0.4	12.1 ± 0.3	0.06
Final	12.2 ± 0.3	11.8 ± 0.3	0.05
p-value	0.07	0.05	
Ht (%)			
Initial	38.0 ± 1.3	36.2 ± 0.9	0.05
Final	36.9 ± 1.2	35.4 ± 1.0	0.04
p-value	0.06	0.08	
$PaCO_2/ETCO_2$			
Initial	1.15 ± 0.04	1.2 ± 0.02	0.01
Final	1.2 ± 0.03	1.2 ± 0.03	1.0
p-value	0.005	1.0	
PaO_2/FiO_2			
Initial	540.0 ± 67.1	527.1 ± 57.1	0.65
Final	404.6 ± 28.6	376.2 ± 52.6	0.15
p-value	< 0.001	< 0.001	

Hb, Hemoglobin; Ht, Hematocrit; $PaCO_2$, Partial Carbonic Gas Pressure; PaO_2, Partial Oxygen Pressure; $ETCO_2$, End Expiration Carbonic Gas; FiO_2, Inspired Oxygen Fraction.

tic pressure was similar in both groups on point by point analysis; however, there was a significant difference when variation was analyzed according to points in time (Fig. 4).

During peritoneal insufflation there were no significant differences between both groups for respiratory system resistance (Rrs) values, which presented a modest, but statistically significant increase ($p < 0.05$) during the period (Fig. 4).

Discussion

Results attained show that Grade I obese, who are more prevalent in our routine practice, have more variations in pulmonary mechanics than the non-obese, even during short and low risk laparoscopic surgeries, such as cholecystectomies. The observation underscores the challenge of anesthesia towards suitable ventilation and less pulmonary complications in these patients.

General anesthesia reduces pulmonary functional residual capacity, leading to the immediate development of atelectasis in dependent pulmonary regions with consequent compression of lung tissue, absorption of alveolar air, and decrease in surfactant function.[4] Moreover, anesthetics, analgesics, as well as other drugs used can affect the respiratory drive center, increasing the risk of Postoperative Pulmonary Complications (PPC). However, the effects on pulmonary volumes and on compliance in obese patients are exacerbated in supine position. System compliance is reduced due to the increase in chest wall mass and to the limited excursion of the diaphragm,[3,4] albeit, to present, this aspect has not been clear in Grade I obese.

Results found are similar to previous studies on the obese regarding mechanical ventilation.[10,14] These studies did not,

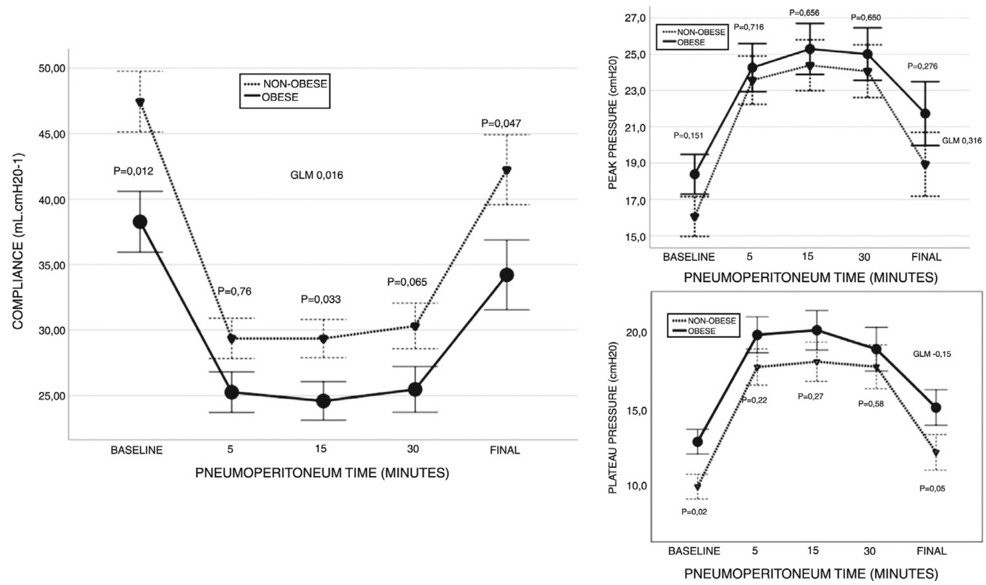

Figure 3 Analysis of individual measurements and variation in pulmonary mechanics in groups during the intraoperative period.

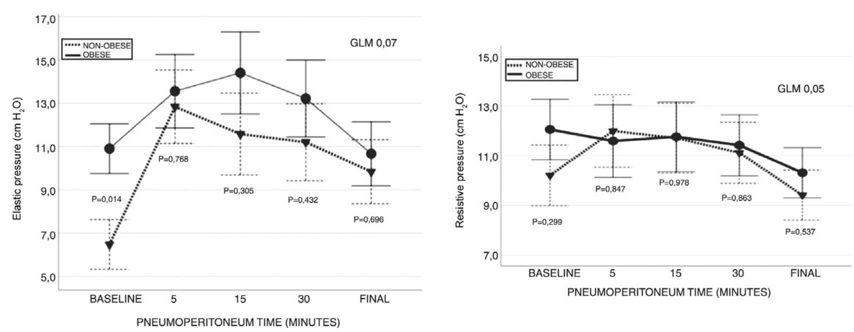

Figure 4 Analysis of individual measurements and variation in elastic and resistive pressures in groups during the intraoperative period.

however, separate Grade I obese from the remaining obese in video laparoscopy, unlike the present study.

The impact of obesity on the respiratory system has been described as the bear hug effect. Fat tissue of the chest wall and in the abdomen may have important effects on chest wall movements, on airway size, respiratory muscle function and on pulmonary perfusion.[8,9]

Obese patients have increased respiratory resistance, underscoring that increased respiratory and pulmonary resistance in the obese is due to reduction in lung volume. The VEF_1/CVF ratio (relation between forced expiratory volume after 1 second and forced vital capacity) is normal in obese patients without lung disease even if resistance is high.[11] Our study did not find significant differences between groups in relation to airway resistance, probably due to lower grade obesity, albeit evidence of a trend towards increased resistance, decreasing after surgery.

Moreover, obesity restricts chest wall mobility and reduces pulmonary volumes, leading to decreased compliance in the respiratory system.[10,13] Partition of lung and chest wall compartments can be obtained using the esophageal balloon technique, in which respiratory changes due to Esophageal Pressure (Pes) estimate changes in Pleural Pressure (Ppl) applied to the lung surface. During mechanical ventilation, the total pressure applied to the respiratory system results from Pressure triggered by the Ventilator (PaW) and the pressure of patients' respiratory muscles. The difference between Paw and Pes is the estimated value of transpulmonary Pressure (P_L) at regions around the esophageal catheter.[12] Monitoring Pes can provide relevant information on the adjustments required to the ventilator, although, to present, there has not been enough evidence to confirm such data. Therefore, we used the technique to estimate pulmonary mechanics in this population.

When compared to baseline values, we observed decrease in compliance of respiratory system with predominance of the pulmonary component in the obese patient group, from peritoneal insufflation until Tfinal. The fact is similar to results reported in the literature.[14–16]

We used oxygenation transfer indices, partial arterial oxygen pressure and inspired oxygen fraction ratio (PaO_2/FiO_2),[17] and found a decrease between initial and Final Times (Tfinal). We did not, however, find differences between the groups, unlike other studies with morbid obese patients ventilated with high tidal volumes,[13,18] which can also be explained by the low-grade obesity.

Moreover, there was no evidence of arterial hypoxemia resulting from abdominal insufflation. Normal oxygenation indicates that ventilation/perfusion or intrapulmonary shunt did not exacerbate.[13,15]

Recently, the multicentric PROBESE[19] study proposed changes in the standards of intraoperative protective mechanical ventilation for obese patients with strategies to prevent postoperative pulmonary complications, recommending low tidal volumes (7 mL.kg^{-1}) and no lung recruitment.

Although the study has relevant information on a specific population, some limitations should be taken into account. First, the size of the sample can be considered small, despite the significant results found, in addition to the fact that the study was carried out only in one center, notwithstanding standardized criteria to keep groups as homogeneous as possible. Moreover, there were a significant number of patients excluded due to failure in the esophageal pressure measuring technique. Last, only female patients were studied, which limits generalization of data, but we strengthened the results found by constraining analysis to the same sample group.

Conclusions

Grade I obese patients' present changes in pulmonary mechanics when compared to the non-obese during laparoscopic cholecystectomies. The decrease in compliance of the pulmonary component of the respiratory system was significantly higher in obese patients. Elastic pressure and resistance presented significantly different variations between groups and during peritoneal insufflation. There was no evidence of arterial hypoxemia resulting from peritoneal insufflation, although decrease in oxygenation indices during pneumoperitoneum was clinically more relevant in the obese, but statistically equal in both groups.

Conflicts of interest

The authors declare no conflicts of interest.

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