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A Comparative Study between Protective Lung Ventilation versus Conventional Ventilation in Obese Patients Undergoing Abdominal Laparoscopic Surgery

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Abstract

Background: Obesity is a serious problem worldwide. During general anesthesia and post-operative period, obese patients more likely to develop post-operative pulmonary complications as atelectasis and impaired pulmonary function compared to non-obese. Intraoperative protective ventilation consisting of low tidal volume, high PEEP and recruitment maneuvers resulted in alveolar recruitment and optimization of intraoperative respiratory mechanics.

Objective: This study tested two strategies of mechanical ventilation in obese patients to find out which is best regarding gas exchange optimization, airway mechanics and atelectasis score.

Methods: Study was a randomized prospective comparative control study was carried out on 50 obese patients with BMI 30-50 kg/m^2. Patients were prepared for laparoscopic cholecystectomy. Patient's selection according to attendees at time of operation as a single numbers were protective ventilation (group A) and a double numbers were conventional ventilation (group B).

Results: Study showed significance between preoperative and postoperative pulmonary function tests and revealed better POST FVC in group A mean 86.04 (± 10.35) L, while in group B was 74.96 (± 14.73) L, p value (0.021). Better POST FEV1 in group A mean 73.56 (± 16.49) L, while in group B was 56.92 (± 8.340) L, p value (0.046). Better post-operative oxygenation in protective ventilation (group A). Mean Post P (A-a) O_2 in group A was 27.93 (±7.76) mmHg, while in group B was 35.82 (±11.98) mmHg, p value (0.022).

Study found peak and plateau airway pressures were higher in protective group with no change in airway resistance. Pulmonary compliance was improved but, in this study revealed more alterations of the hemodynamics in the patients who were subjected to protective ventilation despite adequate preoperative fluid preload.

Hemodynamic instability observed in 24% in group A, but only occurred in 8% in group B. Study found that protective ventilation was superior to standard ventilation in prevention of atelectasis development 64%of the cases in group A revealed normal postoperative CT Chest and 36% showed lamellar atelectasis. In group B, 48% of the cases showed normal postoperative CT Chest, 40% revealed lamellar atelectasis and 12% showed plate atelectasis.

Conclusions: Study found protective ventilation was superior to conventional ventilation in prevention of lung atelectasis and associated with better oxygenation and pulmonary function tests in the post-operative in obese laparoscopic cholecystectomy. In spite of it was very effective in optimizing gas exchange, but associated with more hemodynamic affection.

Keywords: Obese; Laparoscopy; Protective; Lung ventilation; Conventional; Recruitment; Pulmonary function tests

Introduction

Obesity is a worldwide serious problem. Finucane et al. [1] found a worldwide average increase in age-standardized body mass index (BMI, defined as weight (kg)/height (m)^2 [2]. Obese patients have priori healthy lungs; however, the pathophysiological changes induced by obesity make these patients prone to perioperative complications, such as hypoxemia, hypercapnia and atelectasis [3].

Obesity is associated with restrictive lung disease caused by increased intra-abdominal pressure, and decreased chest wall compliance resulting in a decrease in static and dynamic lung volumes [4].

Obese patients are more likely than non-obese patients to develop atelectasis, which resolves more slowly. This is because of a marked impairment of the respiratory mechanics (decreased chest wall and lung compliance and decreased function residual capacity) promoting airway closure with reduction of the oxygenation index (PaO_2/PAO_2) to a greater extent than in healthy weight subjects. Also, the weight of the torso and abdomen makes diaphragmatic excursions more difficult, especially when recumbent or supine, which is intensified in the setting of diaphragmatic paralysis associated with neuromuscular blockade [5].

In obese patients, avoiding atelectasis formation is perhaps particularly difficult but at the same time particularly important [6]. Laparoscopic surgery has developed rapidly over the last few years, and many surgical procedures formerly carried out through large abdominal incisions are now performed laparoscopically. Laparoscopic techniques have revolutionized the field of surgery with benefits that include decreased postoperative pain, earlier return to normal activities following surgery and fewer postoperative complications (e.g., wound infection, hernia) [7].

Laparoscopy is a well-established procedure for laparoscopic cholecystectomy surgery often performed in reversed trendelenburg position. To facilitate laparoscopic surgical manipulation, a pneumoperitoneum is usually induced through carbon dioxide inflation. The increase in abdominal pressure as a result of carbon dioxide inflation has been shown to impair the respiratory function during the procedure, mainly inducing atelectasis formation in the dependent lung regions. The resulting decrease in functional residual capacity poses patients at risk of perioperative complications, particularly if they are obese and/or submitted to intricate surgical procedures [8,9]. For decades, it has been known that general anesthesia can impair oxygenation, even in patients with healthy lungs and it is possible that the application of mechanical ventilation is a contributing factor.

A strategy of protective ventilation, consisting of low tidal volumes and plateau pressures and application of positive end expiratory pressure (PEEP) has gained widespread acceptance in intensive care units after large studies showed an associated reduction in morbidity and mortality in patients with acute lung injury. Information about the respiratory effects of protective mechanical ventilation in the operating room where patients with normal lung function receive mechanical ventilation for a short period is limited [10].

The hypothesis of the current study is that during laparoscopic surgery, both the positioning of the patient and pneumoperitoneum worsen chest wall elastance, concomitantly decrease trans-pulmonary pressure, and that protective lung strategy consisting of low tidal volume, high PEEP and recruitment maneuvers by increasing the trans pulmonary pressure, would result in alveolar recruitment and improvement in respiratory mechanics and gas exchange.

The aim of this study is to evaluate the efficacy of intraoperative ventilation strategy either protective or conventional in obese patients undergoing abdominal laparoscopy as regard intraoperative airway mechanics, oxygenation, hemodynamics and atelectasis score.

(1) After anesthesia induction in supine position (T0).

(2) After CO_2 pneumoperitoneum (T1).

(3) After positioning of patient by 10 min (T2)

(4) After positioning of patient by 30 min (T3).

(5) At the end of surgery, after abdominal deflation in supine position (T4).

On their arrival to the operating theatre, patients were premeditated with IV metoclopramide 10 mg, ranitidine 50 mg and midazolam 0.1 mg/kg in the pre-anesthesia room. After applying Intraoperative monitors, (Draeger Vista 120 monitors, Germany) using 5 leads ECG, pulse oximetry, capnography and non-invasive blood pressure, patients were pre-oxygenated with 100% O_2 for 5 min and general anesthesia was induced with propofol 2 mg/kg, fentanyl 2 µg/kg and succinylcholine 1.5 mg/kg. After oral endotracheal intubation with appropriate size cuffed endotracheal tube, anesthesia was maintained using 1-2 MAC Isoflurane over the period of the operation with fentanyl shots when needed. Neuromuscular blockade obtained by using Atracurium besaylate 0.25 µg/kg as a bolus dose and 5 µg/kg/min as a maintenance dose.

All patients were mechanically ventilated with volume control mode (VCV) (Draeger Fabius plus XL anesthesia machine, Germany) with a respiratory rate 12/min, I:E ratio=1:2 and FiO_2 60%. After induction of anesthesia and positioning of the patient according to the intended laparoscopic intervention (supine, reverse trendelenberg position), Carbon dioxide was insufflated into the peritoneal cavity until the intra-abdominal pressure reached 10-15 mmHg, which was maintained throughout the procedure.

Patients were given 12-15 ml/kg of normal saline intravenously before the induction of anesthesia and were then maintained with 5 ml/kg/h of normal saline solution until the end of the surgery. Intraoperative hypotension (decrease in mean arterial blood pressure [MAP] >25% of baseline) was treated with a bolus of normal saline 0.9% 250 mL and/or incremental doses of IV vasoactive drugs (ephedrine 5 mg). Intraoperative analgesia was achieved by perfalgan 15 mg/kg and nalbuphine 0.25 mg/kg once. At the end of the surgery, Isoflurane was discontinued and FiO_2 was increased to 100%.

The muscle relaxant was reversed by neostigmine 50 µg/kg and 0.015 mg/kg atropine sulfate. Tracheal extubation was performed after reaching satisfactory criteria for extubation. Patients were transferred to the recovery room (PACU) and duration of operation was recorded. In the recovery room, Patients were put in semi-sitting position under basic monitoring and were observed for 30 min for occurrence of any postoperative complications. Oxygen was applied if oxygen saturation decreased <4%. Intraoperative and immediate postoperative complications such as hypoxia, hemodynamic instability either alone or during recruitment maneuver (we marked it as having MAP<60 mmHg or HR<50 b/min), increased $ETCO_2$>45 for more than 1 min, need for reintubation or need for ICU admission were recorded.

Postoperative analgesia during the first 24 h postoperative was maintained by IV ketorolac amp 30 mg every 6 h. All medications and parameters were calculated on an ideal body weight basis. Ideal or predicted body weight (IBW) is calculated according to a predefined formula: (50+0.91 (height (cm)−152.4)) for men and (45.5+0.91 (height (cm)−152.4)) for women [11-13].

Inclusion criteria: ASA class I & II, age ≥ 18 years, BMI ≥ 30 kg/m^2 and <50 kg/m^2, elective abdominal laparoscopic cholecystectomy surgery, free of cardiac, pulmonary, renal or neuromuscular disease and nonsmoker.

Exclusion criteria: ASA III & IV, body mass index (BMI) <30 kg/m^2, previous abdominal surgery, previous lung surgery and hemodynamic instability or intractable shock. The statistical analysis was performed using SPSS 20 (statistical Package for the Social Sciences). Pearson chi-square test was used in analysis of the qualitative variables and the

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student-t test was used for the continuous variables. P value <0.05 was considered statistically significant.

Ethical Considerations

Confidentiality

The confidentiality of all participants admitted to this study will be protected to the fullest extent possible. The study participants will not be identified by name in any report or publication resulting from data collected in this study.

Research statement

Ethical aspects whether substantial or procedural will be implicated in this study. Before participants are admitted in this study, the purpose and nature of the study as well as the risks will be explained to them. The participants must agree that he/she understands the investigational nature of the study, its inherent risks and benefits, his/her rights to terminate participation in this study without affecting his/her rights in having proper health care in the study site, whom to contact with questions regarding the study and that he/she is freely given an informed consent to participate in this study.

Informed consent

The signed informed consent form will be a permanent part of the participant's study records and will be maintained in the same manner as other records.

Results

The current study is a randomized prospective comparative control study which conducted on 50 obese patients with a body mass index (BMI) between 30 and 50 kg/m^2 who were scheduled to undergo elective abdominal laparoscopic cholecystectomy surgery and categorized into to equal groups to evaluate the efficiency of protective lung ventilation strategy and conventional ventilation in this type of patients and surgery. Table 1 and Figure 1 represent sex & age distribution of the studied cases, body mass index (BMI), time of operation and position of the surgery. They reveal that the mean age in group A is 39.28 (± 11.56) years while in group B is 37.65 (± 9.71) years. Mean BMI in group A is 35.21 (± 5.07) kg/m^2, while in group B is 34.57 (± 3.43) kg/m^2. The mean time of operation in group A is 63.6 min, while in group B is 61.6 min.

	A	B	P. Value
	Mean ± SD	Mean ± SD	
Sex			
Male	1 (4%)	1 (4%)	1.000
Female	24 (96%)	24 (96%)	
Age	39.28 ± 11.56	37.65 ± 9.71	0.592
Body mass index (BMI)	35.21 ± 5.07	34.57 ± 3.43	0.602
Time of operation (min)	63.6 ± 10.85	61.6 ± 8.26	0.467

Table 1: Patient characteristics of the two groups, position of surgery and time of operation.

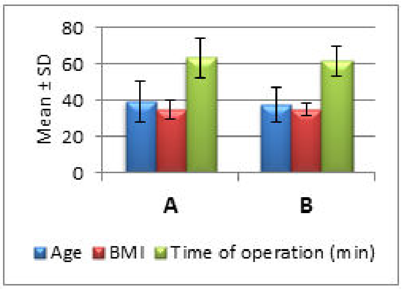

Figure 1: Age, BMI and time of operation of the participants in the study.

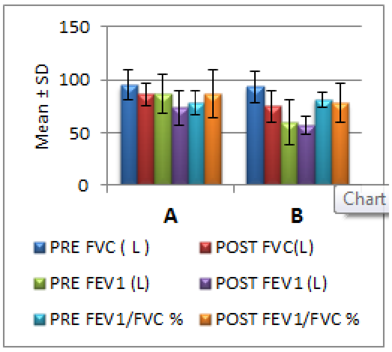

Figure 2: Pre-operative and post-operative pulmonary function tests in group A & B.

Table 2 and Figure 2 show a comparison between pre-operative and post-operative pulmonary function tests done for patients subjected to group A and group B and reveal better POST FVC and POST FEV1 in group A, but no difference in POST FEV1/FVC. POST FVC in group A has a mean of 86.04 (± 10.35) L while in group B mean POST FVC was 74.96 (± 14.73) L with significant p values (0.021). POST FEV1 in group A has a mean 73.56 (± 16.49) L, while in group B, mean POST FEV1 is 56.92 (± 8.340) L with statistically significant p value (0.046).

	A	B	P. Value
	Mean ± SD	Mean ± SD	
PRE FVC (L)	95 ± 14.32	93.04 ± 14.42	0.969
POST FVC (L)	86.04 ± 10.35	74.96 ± 14.73	0.021*
PRE FEV1 (L)	86.64 ± 17.87	60.06 ± 21.35	0.591
POST FEV1 (L)	73.56 ± 16.49	56.92 ± 8.34	0.046*
PRE FEV1/FVC %	78.38 ± 11.53	81.25 ± 7.43	0.092
POST FEV1/FVC %	87.0 ± 23.0	78.0 ± 18.0	0.714
* Statistically significant difference (p<0.05)			

Table 2: Pre-operative and post-operative pulmonary function tests in groups A and B.

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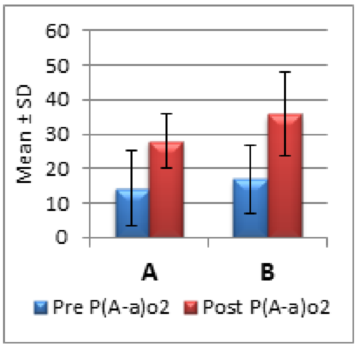

Figure 3: Pre-operative and post-operative Alveolar-arterial O_2 pressure gradient in groups A and B.

	A	B	P. Value
	Mean ± SD	Mean ± SD	
Pre P (A-a)o_2	14.24 ± 10.75	16.91 ± 10.05	0.370
Post P (A-a)o_2	27.93 ± 7.76	35.82 ± 11.98	0.022*
* Statistically significant difference (p<0.05)			

Table 3: Pre-operative and post-operative Alveolar-arterial O_2 pressure gradient in groups A and B.

Table 3 and Figure 3 reveal a better post-operative Alveolar-arterial O_2 pressure gradient (Post P (A-a) O_2) in group A where the mean Post P (A-a) O_2 in group A is 27.93 (± 7.76) mmHg, while in group B is 35.82 (± 11.98) mmHg with statistically significant p value (0.022).

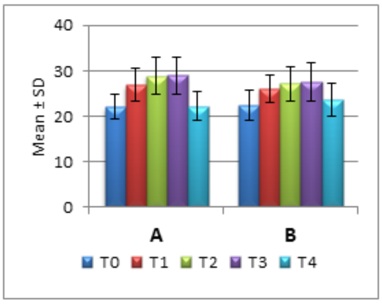

Figure 4: Peak airway pressure during the surgery time.

Table 4 and Figures 4-6 show the study of the airway mechanics during the surgery time. It reveals that airway pressures (peak and plateau) were higher in patients subjected to protective ventilation (group A).

	Peak airway pressure			Plateau airway pressure			Airway resistance		
	A	B	P. Value	A	B	P. Value	A	B	P. Value
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
T0	22.08 ± 2.74	22.44 ± 3.22	0.672	18.8 ± 2.29	19.44 ± 2.79	0.379	3.24 ± 0.97	3.16 ± 0.94	0.769
T1	26.88 ± 3.69	26.04 ± 3.13	0.390	23.68 ± 3.44	22.24 ± 2.52	0.098	3.28 ± 1.02	3.68 ± 1.22	0.214
T2	28.88 ± 3.99	27.2 ± 3.82	0.135	25.44 ± 3.92	23.48 ± 3.32	0.062	3.44 ± 1.26	3.68 ± 1.22	0.496
T3	28.92 ± 3.97	27.52 ± 4.11	0.227	25.76 ± 3.64	23.56 ± 3.74	0.040*	3.12 ± 1.05	4.08 ± 1.98	0.037*
T4	22.16 ± 3.12	23.64 ± 3.71	0.133	18.92 ± 2.98	19.8 ± 3.27	0.325	3.16 ± 1.03	3.84 ± 2.13	0.158
* Statistically significant difference (p<0.05)									

Table 4: Intraoperative airway pressures (airway mechanics) during the surgery time.

Table 5 and Figures 7-9 show the changes in the intraoperative hemodynamics (MAP and HR) and End tidal CO_2 during the surgery time. MAP decreased significantly in group A at T2, T3 and T4 (mmHg; Mean ± SD: 85.76 ± 13.87, 82.84 ± 13.53, 79.2 ± 11.77), p value (0.011, 0.0010.001).

End tidal CO_2 show significant increase in group A at T1, T2 and T3 (mmHg; Mean ± SD: 33.12 ± 2.89, 35.2 ± 3.15, 37.4 ± 3.34), p value (0.030, 0.031, 0.002).

Table 7 and Figure 11 show that 64% of the cases in group A had a normal postoperative CT Chest and 36% showed lamellar atelectasis. In group B, 48% of the cases were normal, 40% revealed lamellar atelectasis and 12% showed plate atelectasis.

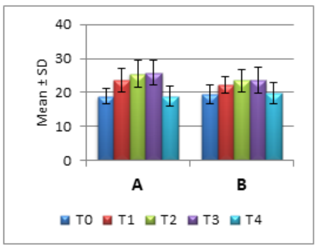

Figure 5: Plateau airway pressure during the surgery time.

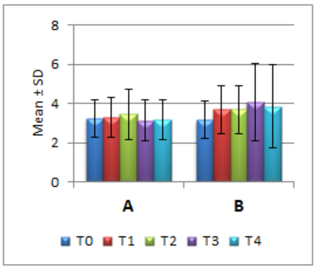

Figure 6: Airway resistance during the surgery time.

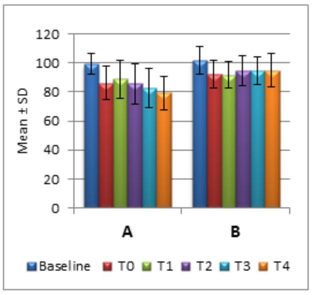

Figure 7: MAP during the surgery time.

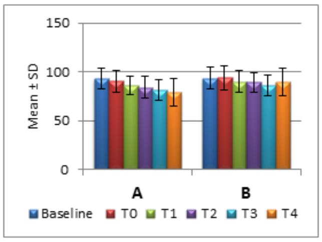

Figure 8: Heart rate during the surgery time.

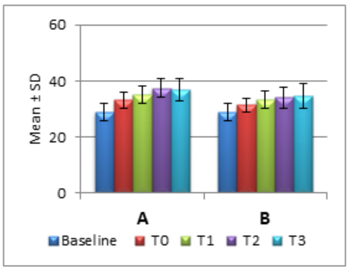

Figure 9: End-tidal CO_2 during the surgery time.

Table 6 and Figure 10 show that the incidence of hemodynamic instability was higher in group A (24%), but only occurred in 8% of the cases in group B.

	Mean arterial blood pressure			Heart rate (HR)			End tidal CO_2		
	A	B	P. Value	A	B	P. Value	A	B	P. Value
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
Baseline	99.4 ± 7.17	101.96 ± 9.70	0.212	93.16 ± 10.65	93.6 ± 11.29	0.562			
T0	86.24 ± 11.59	92.24 ± 9.8	0.054	90.44 ± 11.11	93.92 ± 12.08	0.294	28.92 ± 3.13	28.84 ± 2.95	0.926
T1	88.68 ± 13.24	91.64 ± 9.14	0.362	86 ± 9.9	90 ± 10.9	0.181	33.12 ± 2.89	31.4 ± 2.53	0.030*
T2	85.76 ± 13.87	94.88 ± 10.39	0.011*	83.96 ± 11	89.08 ± 10.34	0.096	35.2 ± 3.15	33.28 ± 2.97	0.031*
T3	82.84 ± 13.53	94.4 ± 9.52	0.001**	81.4 ± 10.63	86.2 ± 10.78	0.119	37.4 ± 3.34	33.96 ± 3.97	0.002**
T4	79.2 ± 1.77	94.96 ± 11.41	0.001**	79.16 ± 13.89	89.72 ± 13.83	0.010*	36.96 ± 3.99	34.72 ± 4.47	0.068
** Highly statistically significant difference (p<0.01); * Statistically significant difference (p<0.05)									

Table 5: Intraoperative Hemodynamics & End-tidal CO_2 during the surgery time.

Discussion

Morbid obesity is considered an epidemic of global proportions. The origin of this problem is multifactorial and includes biological factors related to physical inactivity and inadequate dietary patterns, which are associated, in turn, with psychosocial factors related to the lifestyle adopted by the population [4]. The majority of obese patients presenting for surgery are relatively healthy and their perioperative risk is similar to that of normal weight patients. The patients at high risk of perioperative complications are those with central obesity and metabolic syndrome rather than those with isolated extreme obesity [14]. The number of surgical patients with obesity is increasing; and facing these challenges is common in the operating rooms and critical care units worldwide .While lung protective ventilation with low tidal volumes (VT) and the use of positive end-expiratory pressure (PEEP) and recruitment maneuver are now considered routine for ICU patients, the implementation of protective ventilation strategies in the operating room is not widespread [4,15].

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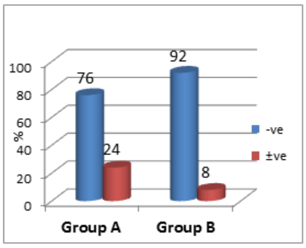

Figure 10: Incidence of the hemodynamics instability in the two groups during the surgery time.

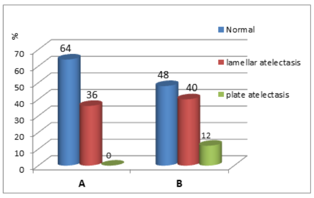

Figure 11: Atelectasis score.

	Mean Hemodynamic instability				P. Value
	Group A		Group B		
	NO.	%	NO.	%	
-ve	19	76	23	92.0	0.247
± ve	6	24	2	8.0	

Table 6: Incidence of the Intraoperative complications (Hemodynamic instability).

	A		B		P. Value
	NO.	%	NO.	%	
Comment on CT					
Normal	16	64	12	48	0.163
lamellar atelectasis	9	36	10	40	
plate atelectasis	0	0	3	12	

Table 7: Postoperative CT Chest and atelectasis score.

These practices may reflect the shortage of convincing prospective trials showing a significant negative impact of non-protective ventilation of short duration on clinical outcomes of patients with healthy lungs. During general anesthesia and the immediate post-operative period, obese patients are more likely to develop post-operative pulmonary complications such as atelectasis and exhibit impaired pulmonary function compared to non-obese individuals. Therefore, the prevention of atelectasis is of utmost importance in this population, because atelectasis affects respiratory mechanics, the volume of airway closure, and the oxygenation index (PaO_2/FiO_2) [16]. With pneumoperitonium occuring during laparoscopy, there are decreases in thoraco-pulmonary compliance by 30% to 50% in healthy and obese patients, further reduction in functional residual capacity, elevation of the diaphragm and pulmonary ventilation perfusion mismatching [17].

This study compared a lung-protective mechanical ventilation strategy combining the use of lower tidal volume (TV), higher PEEP levels, and intraoperative RMs, with a conventional standard mechanical ventilation (higher tidal volume, ZEEP without intraoperative RMs) during abdominal laparoscopic cholecystectomy surgery. In the current study, the aim was not to investigate major post-operative pulmonary complications, but to investigate the effects of intraoperative ventilation strategies on relevant clinical parameters associated with alterations in the pulmonary function. We evaluated the following:

(1) Arterial oxygenation and peripheral oxygen saturation in air.

(2) Pulmonary function tests.

(3) Occurrence of intraoperative or postoperative complications.

(4) Chest CT abnormalities including atelectasis.

(5) Intraoperative airway mechanics.

The study is conducted on 50 obese patients who underwent abdominal laparoscopic surgery at Aswan University Hospital.

Age, sex, BMI and operative time were non-significantly different between the two groups.

Preoperative Pulmonary function tests were comparable pre-operatively in the groups, but FVC and FEV1 were better in the protective ventilation strategy group than in the standard ventilation group one day post-operatively. This finding is consistent with those of Severgnini et al. [18], who reported that FVC and FEV1 were higher in the protective ventilation strategy group than in the standard ventilation strategy group on postoperative days 1, 3, and 5, as well as with the results of Fuiter et al. [19], who reported that a ventilatory strategy with a tidal volume of 6-8 ml/kg BW and a PEEP of 6-8 cm H_2O in either open or laparoscopic surgery improves postoperative respiratory function, reduces the incidence of pulmonary and extra-pulmonary complications and decreases the length of hospital stay compared to a strategy with high tidal volumes and no PEEP.

This result conflicts with that of Grieco et al, who reported that although pulmonary function test results on day 2 showed a similar FEV1 and FEV1/FVC ratio, a higher predicted FVC was found in the patients in a standard ventilation group, possibly because their study was performed on a small sample (only twelve patients) and also because they added 5 cm H_2O of PEEP to the standard ventilation (SV) group.

The study showed that the post-operative alveolar-arterial O_2 pressure gradient (Post P (A-a) O_2) was higher in the patients subjected to protective ventilation. This finding is consistent with Pang et al. [20], who evaluated the effects of PEEP and RM during laparoscopic cholecystectomy on arterial oxygenation: one group of patients was ventilated with ZEEP and a VT of 10 ml/kg, and a second group was ventilated with 10 cm H_2O of PEEP and RM (airway pressure set at 40 cm H_2O for 1 min). The group with PEEP and RM showed improved intraoperative oxygenation. Futier et al. [21] and Aldenkortt et al. [22] also concluded that adding RMs and PEEP in obese patients improved oxygenation. This finding is inconsistent with that of Whalen et al [23], who investigated the effects of different PEEP levels (4 and 8 cm H_2O) and RMs at a fixed VT of 8 ml/kg on intraoperative arterial oxygenation. RMs was performed with a progressive PEEP increase from 10 to 20 cm H_2O. As a result, the PaO_2/FiO_2 ratio significantly increased during pneumoperitoneum insufflation in the PEEP+RM-group, but this effect promptly dissipated at extubation.

The current study uses high level of PEEP (10 cm H_2O) which was maintained in the protective group throughout the procedure. Peak and plateau airway pressures were higher in group (A), leading to increase in the transpulmonary pressure which resulted in alveolar recruitment and improvement in respiratory mechanics and gas exchange. This finding is consistent with that of Almarakbi et al. [24], who demonstrated that alveolar recruitment maneuver (ARM) repeated every 10 min (40 cm H_2O for 15 s) followed by PEEP of 10 cm H_2O throughout the surgical procedure resulted in increased pulmonary compliance as well as with that of Futier et al. [21], who demonstrated that an RM applied after pneumoperitoneum induction and followed by the application of PEEP provides significant improvements in pulmonary compliance and oxygenation both in healthy and obese patients.

Peak and Plateau airway pressures were higher after induction of pneumoperitoneum till deflation of the abdomen in group A, but did not exceed 30 cm H_2O. This result is consistent with that of Severgnini et al, who report that the plateau pressure and the mean airway pressure of the respiratory system were higher in the protective group compared with the standard ventilation strategy group.

The use of high PEEP levels is potentially associated with an increase in mean airway pressure within the respiratory system, likely promoting higher incidence of hemodynamic complications and higher fluids' requirement. This study tried to overcome the deleterious effects of PEEP, recruitment maneuvers and large tidal volumes in both groups by giving sufficient preoperative preload with crystalloid solution (12-15 ml/kg of normal saline intravenously before the induction of anesthesia and were then maintained with 5 ml/kg/h of normal saline solution until the end of the surgery).

However, a greater effect on hemodynamic parameters were observed in the patients who received protective ventilation and RMs. Indeed, hemodynamic instability requiring the administration of fluid boluses and vasopressors, was much higher in group A (observed in 24% of the cases), occurred only in 8% of the cases in group B. This finding is consistent with that of Grasso et al [25], who reported reduced cardiac output (CO) and MAP after the application of RMs in ARDS patients, as well as with that of Nielsen et al. [26], who reported that RMs led to a significant reduction in CO in critical care patients. Almarakbi et al. [24] reported that the patients who were subjected to RMs require more vasopressors. Jo et al. [27] reported decreases in MAP and HR when PEEP was added in the setting of a pneumoperitoneum.

In contrast, Talab et al. [16] reported that the application of PEEP and the vital capacity manoeuver (VCM) was not accompanied by a significant reduction in MAP, even after pneumoperitoneum induction and positioning, possibly because they administered more fluids to the patients before positioning (20 ml/kg/h) and also because the VCM was applied only once immediately after intubation and was maintained for 7-8 s. Additionally, Severgnini et al reported that the use of higher PEEP levels was not associated with major hemodynamic impairments, higher intraoperative fluid requirements or blood loss, probably because they used modified RMs with a progressive increase in tidal volumes, which may have provoked less negative hemodynamic impairment than the use of sustained inflation, as frequently suggested.

Hotchkiss et al. [28] established that large tidal volumes can cause a stretch type of injury (volutrauma), which can lead to lung inflammation. Ventilating patients with low tidal volumes can experience some degree of CO_2 retention. This action may have some beneficial effects, as mild hypercapnia can improve tissue oxygenation through improved tissue perfusion due to increased CO and vasodilatation and increased O_2 off-loading from a shift of the oxyhemoglobin dissociation curve to the right. Hager et al. [29] have shown that mild hypercapnia similarly improves the subcutaneous tissue O_2 tension ($PsqO_2$) in morbidly obese individuals. Pelosi et al. [30] have shown that the current practice of maintaining mild hypocapnia (i.e. $ETCO_2$ values between 30 and 35 mmHg) is controversial due to the reported benefits of permissive hypercapnia in the critical care literature. The current study showed a significant increase in $ETCO_2$ in the protective ventilation group after pneumoperitoneum induction until the end of surgery that did not exceed 45 mmHg. This finding is consistent with that of Way and Hill [31], who concluded that mild hypercapnia ($ETCO_2$ values of approximately 40 mmHg or higher) is beneficial and should be accepted as the standard of care. Grieco et al also reported a lower mean $PaCO_2$ in the standard ventilation group.

During general anesthesia and the immediate post-operative period, obese patients are more likely than non-obese patients to develop atelectasis that resolves more slowly. In obese patients, avoiding atelectasis may be particularly difficult but is also particularly important [32]. The current study evaluated patients in both groups post-operatively *via* chest CT and found that protective ventilation was superior to conventional ventilation in the prevention of atelectasis, as reflected by a higher atelectasis score in the standard ventilation group, in which 52% of the patients developed atelectasis (40% showed lamellar atelectasis and 12% showed plate atelectasis), compared to 36% of the patients in the protective ventilation group (all these cases revealed lamellar atelectasis). This finding in consistent with that of Coussa et al. [33], who reported similar results and concluded that the application of PEEP (10 cm H_2O) in morbidly obese patients was very effective in preventing atelectasis during the induction of general anesthesia, as well as with that of Talab et al. [16], who reported that the application of the VCM followed by 10 cm H_2O of PEEP resulted in better intraoperative and postoperative oxygenation in addition to a lower atelectasis score on chest CT scans approximately 2 h postoperatively than those for the application of the VCM alone. Barbosa et al. [34] performed a meta-analysis and suggested that an open lung approach with PEEP in surgical patients improves post-operative oxygenation and decreases post-operative atelectasis without any adverse events. This result is inconsistent with that of Rothen et al. [35], who reported that the VCM alone could completely abolish atelectasis that developed after the induction of general anesthesia. This finding can be explained by the different patient populations studied, as they applied the VCM to non-obese patients undergoing non-laparoscopic surgery, while we evaluated obese patients undergoing laparoscopic surgery.

Recommendations

The use of protective ventilation with low tidal volumes (approximately 6 mL/kg, calculated based on ideal -not actual- body weight) to avoid volutrauma. Alveolar recruitment maneuver is applied for a number of reasons: using high level of PEEP (20 cm H_2O), performed after induction of anesthesia, after pneumoperitoneum induction and before extubation to optmize gas exchange and to avoid atelectasis during laparoscopic surgery. There should be a close monitoring for the hemodynamics of the patient during recruitment maneuvers. A judicious oxygen should be used (ideally less than 0.8) to avoid hypoxemia and also to decrease the risk of possible reabsorption atelectasis. Postoperative intensive care support should be considered, but it is determined more by comorbidities and surgery than by obesity per se. Further trials are necessary to define the role of intraoperative protective ventilation to prevent postoperative pulmonary complications in obese patients during open abdominal surgery.

References

1. Finucane MM, Stevens GA, Cowan MJ, Danaei G, Lin JK, et al. (2011) National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. Lancet 377: 557-567.
2. Flegal KM, Carroll MD, Ogden CL, Curtin LR (2010) Prevalence and trends in obesity among US adults, 1999–2008. JAMA 303: 235-241.
3. Jaber S, Coisel Y, Chanques G, Futier E, Constantin JM, et al. (2012) A multicentre observational study of intra-operative ventilatory management during general anaesthesia: tidal volumes and relation to body weight. Anesth 67: 999-1008.
4. Pelosi P, Luecke T, Rocco PR (2011) Chest wall mechanics and abdominal pressure during general anaesthesia in normal and obese individuals and in acute lung injury. Curr Opin Crit Care 17: 72-79.
5. Eichenberger A, Proietti S, Wicky S, Spahn DR, Magnusson L, et al. (2002) Morbid obesity and postoperative pulmonary atelectasis: an underestimated problem. Anesth Analg 95:1788-1792.
6. Magnusson L, Spahn DR (2003) New concept of atelectasis during general anaesthesia. Br J Anesth 91: 61-72.
7. Pryor A, Yoo J (2010) Abdominal access techniques used in laparoscopic surgery.
8. Strang CM, Hachenberg T, Fredén F, Hedenstierna G (2009) Development of atelectasis and arterial to end-tidal PCO2- difference in a porcine model of pneumoperitoneum. Br J Anesth 103: 298-303.
9. Valenza F, Chevallard G, Fossali T, Salice V, Pizzocri M, et al. (2010) Management of mechanical ventilation during laparoscopic surgery. Best Pract Res Clin Anaesthesiol 24: 227-241.
10. Ramachandran SK, Nafiu OO, Ghaferi A, Tremper KK, Shanks A, et al. (2011) Independent predictors and outcomes of unanticipated early postoperative tracheal intubation after nonemergent, noncardiac surgery. Anesth 115: 44-45.
11. Tobin MJ (1994) Mechanical ventilation. N Engl J Med 330: 1056-1061.
12. Westcott JL, Cole S (1985) Plate atelectasis. Radiology 155: 1-9.
13. ARDSNet, Brower RG, Matthay MA, Morris A, Schoenfeld D, et al. (2000) Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. The acute respiratory distress syndrome network. N Engl J Med 342: 1301-1308.
14. Glance LG, Wissler R, Mukamel DB, Li Y, Diachun CA, et al. (2010) Perioperative outcomes among patients with the modified metabolic syndrome who are undergoing non cardiac surgery. Anesthesiology 113: 859-872.
15. Fernandez-Bustamante A, Wood CL, Tran ZV, Moine P (2011) Intraoperative ventilation: incidence and risk factors for receiving large tidal volumes during general anesthesia. BMC Anesthesiol 11: 22.
16. Talab HF, Zabani IA, Abdelrahman HS, Bukhari WL, Mamoun I, et al. (2009) Intraoperative ventilatory strategies for prevention of pulmonary atelectasis in obese patients undergoing laparoscopic bariatric surgery. Anesth Analg 109: 1511-1516.
17. Kopelman P (2007) Health risks associated with overweight and obesity. Obes Rev 8: 13-17.
18. Severgnini P, Selmo G, Lanza C, Chiesa A, Frigerio A, et al. (2013) Protective mechanical ventilation during general anesthesia for open abdominal surgery improves postoperative pulmonary function. Anesthesiology 118: 1307-1321.
19. Futier E, Constantin J, Paugam-Burtz C, Pascal J, Eurin M, et al. (2013) A trial of intraoperative low-tidal-volume ventilation in abdominal surgery. N Engl J Med 369: 428-437.
20. Pang CK, Yap J, Chen PP (2003) The effect of an alveolar recruitment strategy on oxygenation during laparascopic cholecystectomy. Anaesth Intensive Care 31: 176-180.
21. Futier E, Constantin JM, Pelosi P, Chanques G, Kwiatkoskwi F, et al. (2010) Intraoperative recruitment maneuver reverses detrimental pneumoperitoneum-induced respiratory effects in healthy weight and obese patients undergoing laparoscopy. Anesthesiology 113: 1310-1319.
22. Aldenkortt M, Lysakowski C, Elia N, Brochard L, Tramer MR (2012) Ventilation strategies in obese patients undergoing surgery: a quantitative systematic review and meta-analysis. Br J Anaesth 109: 493-502.
23. Whalen FX, Gajic O, Thompson GB, Kendrick ML, Que FL, et al. (2006) The effects of the alveolar recruitment maneuver and positive end-expiratory pressure on arterial oxygenation during laparoscopic bariatric surgery. Anesth Analg 102: 298-305.
24. Almarakbi WA, Fawzi HM, Alhashemi JA (2009) Effects of four intraoperative ventilatory strategies on respiratory compliance and gas exchange during laparoscopic gastric banding in obese patients. Br J Anaesth 102: 862-868.
25. Grasso S, Mascia L, Del Turco M, Malacarne P, Giunta F, et al. (2002) Effects of recruiting maneuvers in patients with acute respiratory distress syndrome ventilated with protective ventilatory strategy. Anesthesiology 96: 795-802.
26. Nielsen J, Østergaard M, Kjaergaard J, Tingleff J, Berthelsen PG, et al. (2005) Lung recruitment maneuver depresses central hemodynamics in patients following cardiac surgery. Intensive Care Med 31: 1189-1194.
27. Jo YY, Lee JY, Lee MG, Kwak HJ (2013) Effects of high positive end-expiratory pressure on haemodynamics and cerebral oxygenation during pneumoperitoneum in the Trendelenburg position. Anesth 68: 938-943.
28. Hotchkiss JR, Blanch L, Murias G, Adams AB, Olson DA, et al. (2000) Effects of decreased respiratory frequency on ventilator-induced lung injury, Am J Respir Criti Care Med 161: 463-468.
29. Hager H, Reddy D, Mandadi G, et al. (2006) Hypercapnia improves tissue oxygenation in morbidly obese surgical patients, Anesth Analg 103: 677-681.
30. Pelosi P, Ravagnan I, Giurati G, Panigada M, Bottino N, et al. (1999) Positive end-expiratory pressure improves respiratory function in obese but not in normal subjects during anesthesia and paralysis. Anesthesiology 91: 1221-1231.
31. Way M, Hill GE (2011) Intraoperative End-Tidal Carbon Dioxide Concentrations: What Is the Target? Anesthesiol ResPract Article ID 271539.
32. Coussa M, Proietti S, Schnyder P, Frascarolo P, Suter M, et al. (2004) Prevention of atelectasis formation during the induction of general anesthesia in morbidly obese patients. Anesth Analg 98:1491-1495.
33. Barbosa FT, Castro AA, de Sousa-Rodrigues CF (2014) Positive end-expiratory pressure (PEEP) during anaesthesia for prevention of mortality and postoperative pulmonary complications. Cochrane Database Syst Rev 6: CD007922.
34. Rothen HU, Neumann P, Berglund JE, Valtysson J, Magnusson A, et al. (1999) Dynamics of re-expansion of atelectasis during general anaesthesia. Br J Anesth 82: 551-556.