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Research Article

Effect of low tidal volume during general anesthesia for urological procedures on lung functions

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KEYWORDS

Pulmonary functions;
Lateral position;
Tidal volume

Abstract *Background:* Postoperative lung function impairment is common after surgery specially in the lateral decubitus position. Evidence suggests that if we use low tidal volume during mechanical ventilation this may limit post-operative lung injury. We compared post-operative lung functions in patients put in the lateral position when ventilated with low vs. high tidal volumes.

Methods: This prospective open label clinical trial was performed on 104 patients ASA I&II scheduled for elective urological operations done in the right or left lateral position expected to last more than 2 hours. Patients were divided into two groups: group L ventilated with 5–7 ml/kg tidal volume, with positive end expiratory pressure (PEEP) 10 cm H_2O and recruitment maneuver (RM) and group H ventilated with 10–12 ml/kg tidal volume with zero-end expiratory pressure and no recruitment maneuver. Pulmonary functions were measured pre-operatively and 6, 12, 24 hours after extubation.

Results: Better pulmonary functions were found in the first post-operative six hours in the low tidal volume group and significant difference was found in all parameters. FVC and FEV1/FVC were significantly higher in the low tidal volume group ($P = 0.000$) after 12 hours of extubation. After 24 hours we found significant difference in the predicted FEV1 and FVC and FEV1/FVC ratio ($P = 0.000$) being higher in the low tidal volume group.

Conclusion: In comparison with conventional mechanical ventilation using high tidal volume with zero PEEP and no RM: a lung protective strategy using low tidal volume with 5–10 cm H_2O PEEP and RM did improved lung functions in the first post-operative 24 hours. The overall postoperative follow up did not show significant difference between the two groups.

1. Introduction

The tidal volume is considered the main determinant of ventilation settings during general anesthesia. It is the key factor in volume controlled mechanical ventilation. Recently, the trend to use lower tidal volume during mechanical ventilation is expanding rapidly to decrease lung injury. Postoperative

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pulmonary complications, especially postoperative respiratory failure, are important causes of peri-operative morbidity and mortality [1–4]. Patients who are on mechanical ventilation during surgery experience varying degrees of postoperative lung function impairment, including decreased forced vital capacity (FVC) and forced expiratory volume in one second (FEV 1) which is reflected on the patient's outcome [5]. This is because risk factors for postoperative lung function impairment are many and the list includes the following: the duration, site, and technique of surgery [6,7]. After induction of general anesthesia atelectasis develops within minutes and is a direct source of intra-operative gas exchange abnormalities. These areas of atelectasis can be functionally restored in part by lung recruitment maneuver followed by a substantial level of PEEP, which has been demonstrated to improve intra-operative oxygenation [8]. High tidal volumes (10–15 ml/kg) over-distends non-atelectatic alveoli, in particular in nondependent lung areas. During surgery this may stress the non-atelectatic lung regions, triggering local inflammation [8,9]. The beneficial effects of lower tidal volumes in patients who are on short-term mechanical ventilation have been demonstrated in many studies [10,11]. These studies discussed these effects on patients lying supine. Alterations in distribution of pulmonary ventilation and perfusion are known to occur with change in position especially the lateral and prone positions [12] which is the *aim of this study* that is to evaluate the effect of low tidal volume on lung functions during mechanical ventilation for general anesthesia while patients lying in the lateral position.

2. Methods

This prospective, randomized, open label, clinical trial was performed in the department of anesthesia of Qena University Hospital, South Valley University along the year 2013. The trial was *registered prospectively* at the Australian & New Zealand clinical trial registry with the number ACTRN12614000100695. Written informed *consent* was taken from every patient included in the study. *Ethical* committee approval for this study was provided by the Ethics Committee of Qena faculty of medicine. (Chairperson Prof. Ahmad Abolyosr). Patients scheduled for elective non-laparoscopic urological operations under general anesthesia in *the left or right lateral* position (kidney position) expected to last $\geqslant$2 hours. Age of the patients ranged from 18 to 65 years with normal respiratory, hepatic, and cardiac functions and hemodynamically stable. We excluded patients with body mass index more than 30. We also excluded patients with history of chronic obstructive lung disease, asthma or sleep disorders, heavy smokers (more than 2 packs/day), previous lung surgery, or acute lung injury and lastly those patients with history of neuromuscular diseases or on medications that affect their respiratory system (see Figs. 1 and 2).

2.1. Assigning patients

Patients eligible for the study (104 patients) were randomly allocated into the two study groups as 52 patients per group using random allocation software (windows software, version 1.0, May 2004). The allocation ratio is 1:1, and the group identification paper was put in a sealed and opaque envelops to hide allocation.

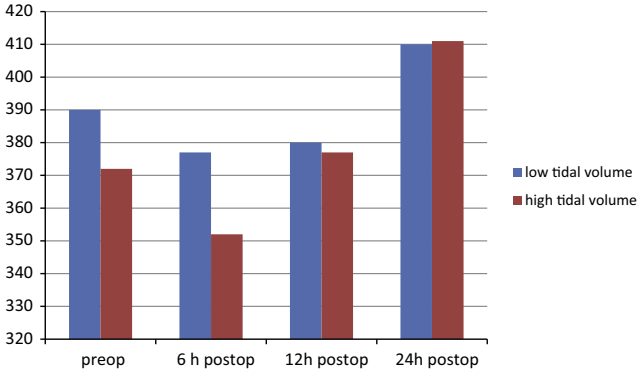

Figure 1 PaO_2/FiO_2 data are expressed as mean ± SD. *P* value is significant at preoperative and 6 hours postoperative time points.

2.2. Anesthesia

Before induction of general anesthesia and for the purpose of perioperative pain relief epidural catheter was inserted at the lumber 2–3 level whenever not contraindicated, otherwise systemic opioids in the form of repeated doses of 1–2 ug/kg fentanyl I.V. were used for pain relief. 34 patients were subjected for epidural catheter insertion. 16 patients were in the group of low tidal volume and 18 patients were in the group of high tidal volume. They received 10 ml lidocaine 2% and 10 ml bupivacaine 0.5% before induction of anesthesia. Postoperatively: 5 ml lidocaine 2% plus 50:100 ug fentanyl was administered through the catheter in repeated doses as guided by pain assessment score specially before spirometry. The rest of patients (70 patients) received systemic fentanyl. The major contraindication for epidural block was patient refusal. Induction and maintenance of general anesthesia were done by the same drugs in all patients in both groups. We used propofol (1%) in a dose of 2 mg/kg preceded by fentanyl 1–2 ug/kg I.V. Tracheal intubation was facilitated by using rocuronium 0.4–0.8 mg/kg I.V. Anesthesia was maintained by sevoflurane in oxygen (FiO_2 = 0.4) during the whole anesthesia period. Patients were monitored during anesthesia for heart rate, ECG, noninvasive blood pressure, pulse oximetry, end tidal carbon dioxide level (Nihon kohden, Japan). An arterial catheter was inserted in the radial artery near the wrist joint for arterial sample withdrawal for blood gas analysis, also a central venous line was inserted in the right or left internal jugular vein in all patients. We followed a conservative fluid infusion of 12–15 ml/kg/h during the operative time to ensure sufficient fluid replacement.

2.3. Positioning

After induction of general anesthesia and assuring that monitoring and venous lines are fixed in position: patients were turned to one side: right or left according to the planned side of surgery. After raising the kidney rest proper position of the head, shoulders, and the endotracheal tube was checked after turning the patient to one side.

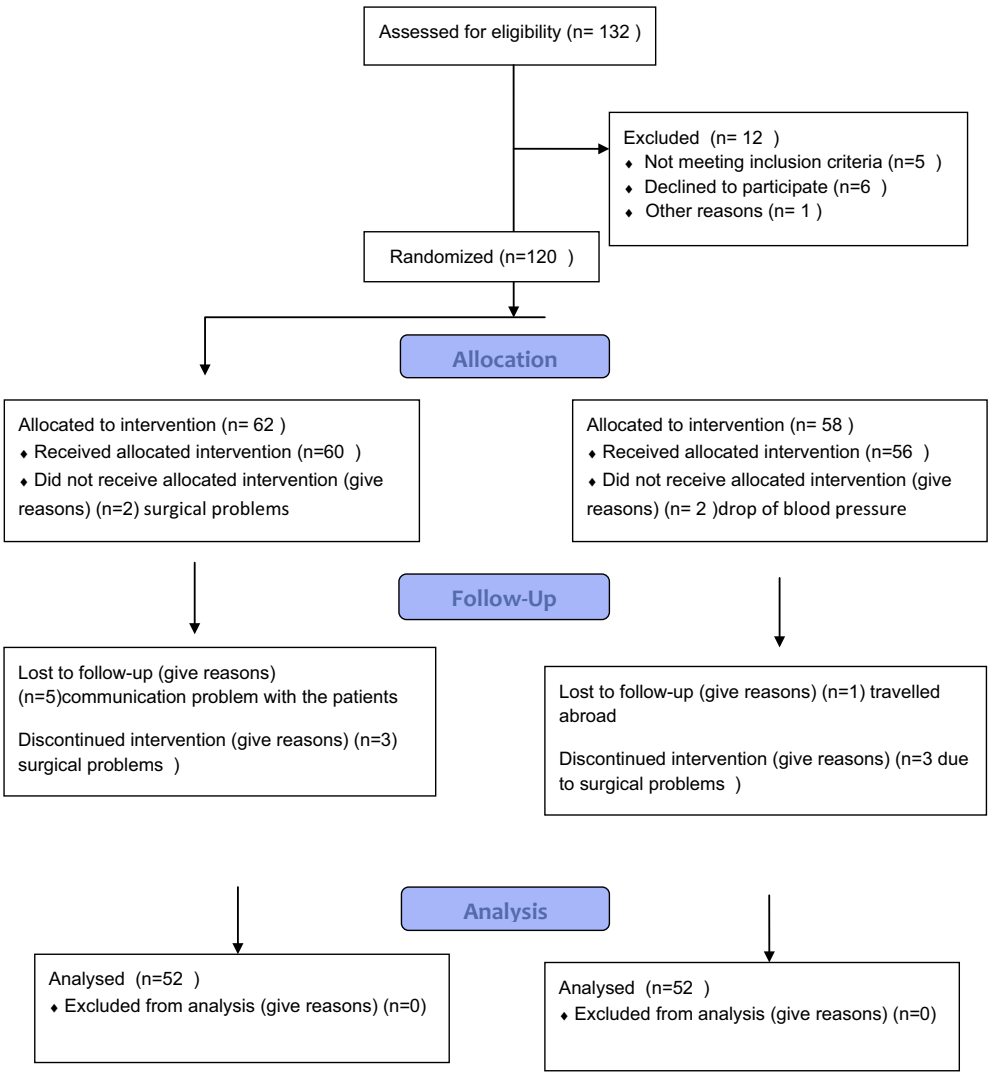

Figure 2 The study flow chart.

2.4. Ventilation protocol

Patients scheduled to two groups: in both groups we applied volume controlled mechanical ventilation using (Datex Ohmeda A 7100 GE Healthcare, Finland). The fraction of inspired oxygen (FiO_2) was 0.4 and the inspiratory to expiratory time ratio is 1:2. The respiratory rate was adjusted to keep normocapnia. In group (**L**) (52 patients): tidal volume was set at 5–7 ml/kg of predicted body weight (PBW) with PEEP 10 cm H_2O, while in group (**H**) (52 patients) tidal volume was set at 10–12 ml/kg of predicted body weight (PBW) and zero-end expiratory pressure (ZEEP).the predicted body weight for male patients, was calculated as follows: weight in kg = 50 + 0.91 × (height in cm – 152.4); and for female patients: weight in kg = 45.5 + 0.91 × (height, in – 152.4). Intra-operative airway pressure, tidal volume, and the respiratory rate were measured by means of the facilities of the anesthesia machine. The compliance of the respiratory system was calculated as follows: tidal volume/(plateau pressure of the respiratory system − PEEP).

2.5. Recruitment maneuver (RM)

In group L in whom low tidal volume was set recruitment maneuver was performed directly after induction of anesthesia, and before extubation. RMs were performed by raising the limit of peak inspiratory pressure to 45 cm H_2O, the tidal volume at 5–7 ml/kg PBW, and respiratory rate at 6 breaths/min, PEEP at 10 cm H_2O, and the inspiratory to expiratory ratio at 3:1; then the tidal volume was increased in steps of 4 ml/kg PBW until plateau pressure reached 30 cm H_2O and three breaths were allowed. Finally, the respiratory rate, the inspiratory to expiratory ratio, inspiratory pause, and tidal volume were set back to values preceding the RM, whereas the PEEP was maintained at 10 cm H_2O. Arterial blood gas analysis was done immediately before and after each RM.

2.6. Spirometry: post-operatively

Patients were asked to rate their pain at rest in the supine position with 30° upper body elevation on a numeric rating scale of

0–10 (0, no pain; 10, maximum pain). If pain score is more than 3 then pain therapy was optimized before Spirometric testing was performed. If an epidural catheter was in place we inject 5 ml of 2% lidocaine plus 50–100 ug fentanyl through the catheter, otherwise fentanyl 50–100 ug was injected intravenously and pain score was reassessed. Measurement of pulmonary function was performed using the spirometer: (VIA SYS, HEALTH CARE, microlab, England) before induction of anesthesia and at 6, 12, and 24 hours after extubation. Patients received detailed instructions about how to do the tests. Measurements were taken in accordance with the American Thoracic Society's standards [13]. All measurements were taken in the supine position with 30° upper body elevation. A clip was placed over the nose and the patient breathed through the mouth into a tube connected to the spirometer. First the patient breathed in deeply, and then exhaled as quickly and forcefully as possible into the tube. This was done three times and the best of the three results was recorded as the measure of lung function and selected for analysis. Arterial blood gas analysis was performed before and after each spirometric measurement.

2.7. Chest radiography

Preoperative and postoperative chest radiographs were performed. Results were scored by a radiologist unaware of group assignment using a Radiological Atelectasis Score: 0, clear lung field; 1, plate like atelectasis or slight infiltration; 2, partial atelectasis; 3, lobar atelectasis; 4, bilateral lobar atelectasis.

2.8. Measurements and follow-up

Blood loss and fluid administration including allogenic blood, vital signs, core temperature, ventilator settings, FiO_2, end-tidal CO_2, and airway pressures were recorded at 15 min intervals throughout surgery, and blood gas analyses were performed before and after RM and whenever indicated. We also measured FEV1 and FVC and their predicted values and FEV1/FVC%. We followed patients for one week after operations (by telephone call if they are discharged from the hospital) for the possible postoperative complications such as: respiratory troubles, cardiac problems, renal insufficiency, delayed wound healing, postoperative bleeding, and wound infection.

2.9. Statistical analysis

The primary outcome variable was FEV1, and FVC pre-to-postoperative change. Sample size calculation was based on previously published data in the literature about change in pulmonary function test results with change in tidal volume [14]. We found that a minimum of 46 patients per group would be sufficient to provide an 80% power of detecting a 20% relative change in FVC and FEV1. Data are presented as mean with standard deviation for parametric and continuous data or numbers and percentage for nonparametric and non-continuous data. Baseline comparisons between groups (high and low tidal volume anesthesia) were made with the independent Student *t* test, while χ^2 test, or Fisher Exact test "if cell number five or less than five" both used when appropriate such as in comparing smoking, temperature above >38 and presence of cough, dyspnea and tracheal secretion with high and low tidal volume anesthesia. *P* value less than 0.05 was considered significant.

3. Results

The *patient characteristics* did not differ significantly regarding age, weight, height, or ASA status. The operative time also was comparable as most of the surgeries were done by the same surgery team (Table 1).

3.1. Pulmonary functions

We measured pulmonary functions pre-operatively, 6 hours, 12 hours and 24 hours after surgery.

3.2. Pre-operatively

We found significant difference between the two groups regarding the predicted FEV1 and the FVC being lower in the low tidal volume group while we found significant difference regarding the PaO_2/FiO_2 ratio being higher in the high tidal volume group (Table 2).

Other pre-operative pulmonary functions such as FEV1, FVC predicted %, and FEV1/FVC showed no significant difference between groups.

6 hours: Measuring pulmonary functions *six hours* after extubation showed significant difference between groups in all parameters measured being better (higher) in the low tidal volume group (group L) (Table 3).

12 h later we found significant difference between the two groups regarding FVC, predicted FVC, predicted FEV1, FEV1/FVC ratio (Table 4).

The data showed better pulmonary function in the low tidal volume group.

After *24 hours* of extubation the results showed significant difference between the two groups regarding the predicted values of FEV1, FVC predicted %, and the FEV1/FVC ratio being better in the low tidal volume group (group L) (Table 5).

The intra-operative data were comparable between the two groups as the anesthetic technique was the same in all patients

Table 1 Patient characteristics (data are expressed as mean ± SD).

	Group L ($n = 52$)	Group H ($n = 52$)	*P* value
Age (years)	40.13 ± 8.27	42.67 ± 9.7	0.281
Weight (kg)	75.03 ± 7.6	76.93 ± 6.19	0.294
Height (cm)	169.63 ± 20.43	169.83 ± 5.44	0.959
Sex	38/14	36/16	–
Operative procedures:			
Stone kidney	32	28	
Stone upper ureter	15	17	
PUO	4	5	
Nephrectomy	1	2	
Tobacco smokers	20.7%	23.3%	0.81
ASA status (I, II)	41/11	43/9	0.85
Patients received lumber epidural	16/52	18/52	–

PUO: pelvi-ureteric obstruction.

Table 2 Preoperative pulmonary functions (mean ± SD).

	Group L (n = 52)	Group H (n = 52)	P value
FEV1	3.44 ± 0.45	3.61 ± 0.57	0.189
FEV1 Predicted %	83.5 ± 12.25	91.1 ± 11.66	0.017*
FVC	3.42 ± 0.6	4.01 ± 0.08	0.000**
FVC pred. %	79.93 ± 10.7	82.87 ± 7.13	0.219
FEV1/FVC %	94.4 ± 16.7	96.33 ± 16.23	0.652
P/F ratio	390.7 ± 22.05	372.07 ± 28.25	0.006*

FEV1 forced expiratory volume in one second.
FVC forced vital capacity.
P/F ratio: PaO_2/FiO_2 ratio.
* Significant P value.
** Highly significant.

Table 3 Postoperative pulmonary functions after 6 hours (mean ± SD).

	Group L (n = 52)	Group H (n = 52)	P value
FEV1	1.96 ± 0.2	1.036 ± 0.461	0.000**
FEV1 pred. %	36.67 ± 7.78	25.53 ± 8.15	0.000**
FVC	2.044 ± 0.311	1.52 ± 1.11	0.016*
FVC pred. %	44.23 ± 10.07	24.87 ± 4.78	0.000**
FEV1/FVC %	62.2 ± 7.6	43.03 ± 15.84	0.000**
P/F ratio	377.98 ± 25.05	352.08 ± 31.87	0.001**

FEV1 forced expiratory volume in one second.
FVC forced vital capacity.
P/F ratio: PaO_2/FiO_2 ratio.
* Significant P value.
** Highly significant.

Table 4 Postoperative pulmonary functions after 12 hours (mean ± SD).

	Group L (n = 52)	Group H (n = 52)	P value
FEV1	3.42 ± 4.87	2.88 ± 3.17	0.291
FEV1 pred. %	58.23 ± 9.43	35.83 ± 9.015	0.000*
FVC	2.62 ± 0.36	2.25 ± 0.29	0.000**
FVC pred. %	82.27 ± 8.7	61.2 ± 8.9	0.000**
FEV1/FVC %	65.53 ± 8.09	45.3 ± 5.26	0.000*
P/F ratio	38O.77 ± 25.92	377.68 ± 29.2	0.667

FEV1 forced expiratory volume in one second.
FVC forced vital capacity.
P/F ratio: PaO_2/FiO_2 ratio.
* Significant P value.
** Highly significant.

(apart from tidal volume and PEEP). During the recruitment maneuver we recorded lower mean arterial blood pressure in the low tidal volume group with P value 0.032.

No perioperative changes in SpO_2 were observed or recorded during perioperative monitoring of this parameter as patients were well oxygenated during operation and postoperative time.

The end tidal carbon dioxide was significantly higher in the low tidal volume group during RM (Table 6).

Table 5 Postoperative pulmonary functions after 24 hours (mean ± SD).

	Group L (n = 52)	Group H (n = 52)	P value
FEV1	1.78 ± 0.43	1.97 ± 0.29	0.281
FEV1pred. %	67.6 ± 8.59	38.8 ± 4.6	0.000**
FVC	3.04 ± 0.51	2.98 ± 0.2	0.587
FVC pred. %	71.53 ± 7.3	52.57 ± 6.12	0.000**
FEV1/FVC %	86.8 ± 8.6	71.4 ± 4.8	0.000**
P/F ratio	410.3 ± 36.7	411.42 ± 44.22	0.915

FEV1 forced expiratory volume in one second.
FVC forced vital capacity.
P/F ratio: PaO_2/FiO_2 ratio.
* Significant P value.
** Highly significant.

Table 6 Intra-operative data (mean ± SD).

	Group L (n = 52)	Group H (n = 52)	P value
Tidal volume (ml)	388 ± 12	795 ± 11	0.000**
Respiratory rate (cycle/min)	11.07 ± 0.82	10.93 ± 0.74	0.513
P_{max} (cm H_2O)	18.3 ± 2.26	16.87 ± 6.17	0.325
P_{plat} (cm H_2O)	10.16 ± 2.19	11.6 ± 1.8	0.311
Compliance	63.28 ± 20.86	68.91 ± 10.9	0.196
PaO_2 before extubation (mm hg)	403 ± 12	406 ± 8	0.927
Heart rate during RM (beat/min)	71 ± 5	77 ± 6	0.871
MAP during RM (mm hg)	77 ± 5	87 ± 2	0.032*
$et\ CO_2$ (mm hg)	29.2 ± 3.7	25.4 ± 2.38	0.000**
Fluids (ml/kg/h)	11 ± 0.8	12 ± 0.6	0.634
Urine output (ml/kg/h)	6 ± 2	6 ± 1.7	0.881
Duration of surgery (min)	133 ± 7	138 ± 5	0.920

P_{max}: maximum airway pressure.
P_{plat}: plateau airway pressure.
PaO_2: arterial oxygen tension.
RM: recruitment maneuver.
MAP: mean arterial pressure.
$et\ CO_2$: end tidal CO_2 pressure
* P value statistically significant.
** Highly significant.

Following our patients in the post-operative 7 days we found no significant differences between the two groups regarding the incidence of fever, cough, dyspnea, the pain score and the X-ray changes. No difference was found regarding total analgesic consumption (Table 7).

4. Discussion

The results of this prospective randomized open label clinical study showed that in comparison with conventional mechanical ventilation using high tidal volume with zero PEEP and no RM, a lung protective strategy using low tidal volume with 10 cm H_2O PEEP and RM did improved lung functions and arterial oxygenation in the first post-operative 24 hours. The

Table 7 Postoperative follow up parameters.

	Group L (n = 52)	Group H (n = 52)	P value
Temp above 38	7 Cases	6 Cases	0.754
Cough, dyspnea	8 Cases	6 Cases	0.542
VAS (median-IQR)	4.2 (3.8–4.23)	3.95(3.18–4.03)	0.324
Analgesic dose (ug fentanyl)	372.1 ± 72	390.63 ± 65	0.232
Atelectasis on CRX	2 Cases	3 Cases	0.986
Length of hospital stay (h)	32 ± 3	33 ± 4	0.962

VAS: visual analog score.
IQR: interquartile range.
CRX: chest X-ray.
h: hours.
No significant difference was found between groups.

overall postoperative follow up did not show significant difference between high and low tidal volume groups.

Post-operative pulmonary dysfunction is common due to reduced ventilatory muscle activity, diaphragmatic dysfunction and decreased lung compliance. This is specially more evident in upper abdominal surgery, chest surgery, and when the patient is turned to one side as in kidney and upper ureter operations [15]. The management of intra-operative airway mechanics as peak airway pressure, plateau pressure, respiratory rate and tidal volume with their impact on lung compliance may not be sufficient to reduce postoperative atelectasis and impaired lung functions. Hence we used the lung protective strategy to maintain lung expansion and minimize the mechanical shear stresses on lung parenchyma. This strategy involves the use of recruitment maneuver (RM) to promote re-expansion of atelectasis, followed by ventilation with relatively high PEEP to prevent reformation of atelectasis and lower tidal volumes to minimize mechanical stresses.

Previously published studies [8–10,12] about the use of lung protective ventilation strategy during general anesthesia with mechanical ventilation showed conflicting opinions regarding the beneficial effect of this method on postoperative lung functions. In fact we did not find published studies on the low tidal volume strategy for patients put in the lateral position during general anesthesia. The published studies were about patients put in the supine position and some studies were with and some were against this strategy. This conflict comes from the fact that these studies were performed on non-homogenous groups of patients, for example cardiothoracic surgery [16], esophagectomy [17] and major abdominal surgery [14] with different end points whether pulmonary functions, systemic inflammation, or alveolar coagulopathy. In addition RM was seldom applied and PEEP levels were variable.

Another issue regarding the different results of these studies is that there was no standardization regarding fluid therapy, hemodynamic parameters and post-operative pain control in these studies.

Treschan [14] and colleagues published in 2012 a double-blind, prospective, randomized controlled clinical trial done on a hundred and one patients (age ⩾ 50 yr, ASA ⩾ II and duration of surgery ⩾ 3 hours) who were ventilated with: high (12 ml/kg) or low (6 ml/kg) tidal volumes intra-operatively. The positive end-expiratory pressure was 5 cm H_2O in *both* groups. Forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV1) were measured until 120 hours after operation and compared (P = 0.025 considered statistically significant). Secondary outcomes were oxygenation, respiratory and non-respiratory complications, length of stay and mortality. They concluded that: (Prolonged impaired lung function after major abdominal surgery is not ameliorated by low tidal volume ventilation). They also stated that intraoperative lung mechanics and gas exchange were better and atelectasis was less with high tidal volume, and that in order to improve lung mechanics they should use higher PEEP in the low tidal volume group that may have hemodynamic effects. Another cause why they did not use high PEEP is the fear that higher levels of PEEP may be associated with high levels of proinflammatory cytokines and pulmonary coagulation activation.

This was not the case in our study as we did not apply PEEP in the high tidal volume group which may affect lung mechanics differently, second we used PEEP levels higher than 5 cm water in the low tidal volume group while monitoring heart rate and arterial blood pressure not to impair these parameters, but we did not measure proinflammatory cytokines to assess the effects of low tidal volume with PEEP and RM on the inflammatory response to this technique.

Severgnini [18] and colleagues in 2013 conducted a study on 56 patients scheduled to undergo elective open abdominal surgery under general anesthesia with mechanical ventilation lasting more than 2 hours. Patients were assigned to either 9 ml/kg with zero-PEEP and no RM group or 7 ml/kg with PEEP of 10 cm H_2O and RM. Pulmonary function tests, arterial oxygenation and modified pulmonary infection score were measured. They found improved pulmonary functions measured over 3 days postoperative in the low tidal volume group more than in the high tidal volume group without effect on the length of hospital stay. This study resembles our study in the settings of mechanical ventilation but our study is different in many aspects. First: our patients were turned to one side during surgery (kidney position) while the patients were put in the supine position in the study of Severgnini. Second: we used tidal volume of 5–6 ml/kg and 10–12 ml/kg in the low and high tidal volume groups respectively. Third: we measured the pulmonary function for 24 hours post-operative only because we found in many published studies that pulmonary functions did not show any difference between low and high tidal volume groups after the first 24 hours postoperative provided that pain control is adequate, in addition; our patients were discharged within 36–48 hours (this is the policy of the urology department). Our study was also different from other studies regarding low tidal volume effect on postoperative pulmonary functions in that we evaluated potential complications of higher PEEP levels and RMs during general anesthesia not in the intensive care setting; again we evaluated the effect of this technique in the lateral position which was not done before. During RM we recorded significant difference in mean arterial blood pressure being lower in the low tidal volume group. It is known that the use of high PEEP levels is associated with an increase in mean airway pressure within the respiratory system which leads to higher incidence of hemodynamic complications [19]. The PEEP level we used was not associated with major hemodynamic impairment although the difference between the two groups was statistically but not clinically significant. In other words: use of RMs was associated with no life-threatening reductions in mean arterial

pressure and heart rate, and no other complications were observed during RM in our study.

The end tidal carbon dioxide level was statistically significantly higher in the low tidal volume group and this expected due to increase in dead space fraction and when you decrease the respiratory rate during RM and although it was not clinically significant and transient (during RM) we corrected it by manipulating the respiratory rate and minute ventilation as appropriate.

In this study we investigated major postoperative complications with relevant clinical parameters associated with alterations in the pulmonary function. We evaluated arterial oxygenation changes, the incidence of patient's temperature above 38 °C, the presence of dyspnea, cough, and secretions, and chest X-ray, abnormalities, including atelectasis. We also evaluated the quality of analgesia and the length of hospital stay which all showed no significant difference between groups. This may be attributed to the use of the same general anesthesia protocol regardless of the tidal volume and that the surgical team was the same for all patients and we could not find relevant difference in the incidence of post-operative atelectasis. This is in contrast to the results of the study of Severgnini [18] and colleagues who reported statistically significant chest X ray alterations in the high tidal volume group at day 1 and 3 which was explained by gross atelectasis and potential peripheral airway injury, caused by tidal airway closure, which was maintained in the postoperative period.

The lateral decubitus position is characterized by special features. The effect of this position on patient's hemodynamics and respiratory parameters (ventilation/perfusion ratio) is investigated in many studies.

Gianinis [20] and colleagues in 2013 published a study done on 30 awake young persons, mean age 22.7 years, healthy and non-smokers. They measured the peak expiratory flow of these subjects in the lateral and dorsal positions and found it lower in the dorsal position than the right lateral with no difference between the sitting and the left lateral which means that the change in position of the patient can affect pulmonary functions.

Manikandan and Rao [12] in 2002 investigated the effect of surgical position (supine, lateral and prone) on gas exchange in *neurosurgical* patients. They performed the study on 69 neurosurgical patients (21 supine, 17 lateral and 31 prone). Arterial blood gas analysis was done pre-induction of anesthesia, post-induction and 30 min after surgical positioning. They reported (there was a 3.5 ± 11.3% decrease in PaO_2 in supine position. On the contrary, lateral and prone positions were associated with 8.1 ± 14.2% and 14.3 ± 15.1% increases in PaO_2 respectively. These changes may not have any clinical consequences in patients with normal preoperative pulmonary function. However, in patients with concomitant acute lung injury such as what happens in head trauma and prolonged unconsciousness, PaO_2 changes of the magnitude reported in this study may become clinically relevant).

This study although proved that the lateral position was associated with improved oxygenation it did not show the effect of that position on pulmonary functions as we did in our study. They did not use lung protective ventilation which can improve oxygenation even in the supine position.

Yokoyama and colleagues [21] in 2000 performed a study on 12 patients undergoing nephrectomy in the lateral position under isoflurane anesthesia compared with 8 patients put in the lateral position without raising the kidney rest. Mean arterial pressure and pulmonary artery wedge pressure were significantly reduced in the nephrectomy group position while the systemic vascular resistance index was increased significantly resulting in decreased cardiac output. These results show the effect of kidney rest and lateral position on the hemodynamic parameters of the patients which should be reflected on the respiratory variables and ventilation/perfusion balance. In our study the effects of lateral position with kidney rest on pulmonary functions and oxygenation were investigated and it can complete our informations about this position during general anesthesia regarding cardio-respiratory variables.

This study had some limitations: first the study did not investigate if there is a difference between right and left decubitus positions as there is anatomical difference between the two sides of the body. Second follow up of the patients was for only 24 hours. Third: the lateral position should have been compared with the supine position. Lastly: ventilation/perfusion ratio was not investigated and we did not measure proinflammatory cytokines to assess the effects of low tidal volume with PEEP and RM on the inflammatory response to this technique.

5. Conclusion

We found that in comparison with conventional mechanical ventilation using high tidal volume with zero PEEP and no RM, a lung protective ventilation strategy using low tidal volume with 10 cm H_2O PEEP and RM did improved lung functions and arterial oxygenation in the first post-operative 24 hours. The overall postoperative follow up was comparable with high and low tidal volume groups.

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Conflict of interest

The authors declare no conflict of interest to this study.

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