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Comparison of the effects of 2 ventilatory strategies using tidal volumes of 6 and 8 ml/kg on pulmonary shunt and alveolar dead space volume in upper abdominal cancers surgery

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Abstract

Background: High tidal volume leads to inflammation, and low tidal volume leads to atelectasia and hypoxemia. This study was conducted to compare the effect of 6 mL/kg with positive end-expiratory pressure (PEEP) and 8 mL/kg without PEEP on pulmonary shunt and dead space volume.

Methods: This clinical trial was done on 36 patients aged 20 to 65 years old with ASA I-II. They were candidates for upper abdominal surgery and divided randomly into 2 groups. One group were ventilated with the tidal volume = 8 mL/kg without PEEP (TV8). The other group received the tidal volume = 6 mL/kg with low PEEP = 5 cm H_2O (TV6). Arterial and central venous blood gases were taken after intubation and 2 hours later. Additionally, the vital signs of the patients were checked every 30 minutes. Data analysis was performed using t test, chi-square test, and repeated measures analysis of variance with SPSS software, version 16 (SPSS Inc). P value less than .05 were meaningful.

Results: There was no significant difference on the preanesthesia parameters. The pulmonary shunt was 13.5±0.1% and 18.6±0.2% in the groups TV6 and TV8, respectively (p=0.132), which slightly decreased after 2 hours in both groups without any significant difference (p=0.284). Prior to the ventilation, the ratios of dead space to tidal volume were 0.25±0.2 and 0.14±0.1 in the TV6 and TV8 groups, respectively (p=0.163), and after 2 hours, they were 0.23±0.11 and 0.16±0.1 in the TV6 and TV8 groups, respectively (p=0.271). There was no significant difference between the groups for blood pressure and peripheral and arterial oxygenation changes.

Conclusion: The tidal volume of 6 mL/kg with the PEEP of 5 mmHg was similar to the tidal volume of 8 mL/kg without PEEP for hemodynamic and pulmonary changes (oxygenation, shunt, and dead space).

Keywords: Mechanical Ventilation, Tidal Volume, Pulmonary Shunt, Positive End-expiratory Pressure

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Introduction

In the recent decades, the use of high tidal volume ventilation (between 10 and 15 mL/kg) was been routine to prevent hypoxemia and atelectasis in abdominal and thoracic surgeries (1, 2). However, empirical and clinical evidence suggest that mechanical ve ntilation, with high tidal volume, with or without positive end-expiratory pressure (PEEP), can exacerbate or even initiate lung injury and cause alveolar over distension and ventilator-induced lung injury (3, 4).

According to the literature, lung protective mechanical

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↑What is "already known" in this topic:
During intraoperative ventilation, the tidal volume of 6 mL/kg is similar to 8 mL/kg, and there is no difference between the 2 volumes in lung physiology and hemodynamic parameters.

→What this article adds:
Using a lower tidal volume with the positive end-expiratory pressure (PEEP) is a good alternative to larger volumes and may cause fewer pulmonary inflammatory complications in long-lasting surgery.

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ventilation with lower tidal volumes (6-8 mL/kg), moderate PEEP (6-8 cmH_2O), and alveolar recruitment maneuver improves the physiological function of the lung and postoperative clinical outcome in abdominal surgeries (5).

Atelectasis is one of the postoperative pulmonary complications that occur after the use of both inhalational and intravenous anesthetics (6). This condition occurs in a few minutes after the induction of anesthesia in 80% to 90% of patients, and 15% to 20% of the lung capacity can collapse during anesthesia before surgical incision (7-9). It is worth mentioning that the true pulmonary shunt is about 5% to 10% of the cardiac output (9-11). Moreover, there is a strong and distinct association between atelectasis and the pulmonary shunt fraction.

The application of PEEP and high tidal volume leads to the fast restoration of lung function as well as prevention of atelectasis (12-14). Nevertheless, the prevention of atelectasis using ventilator strategies remains controversial. In addition, it may impair hemodynamics and even oxygenation. On the other hand, low tidal volumes can be associated with increased incidence of atelectasis.

High tidal volume might lead to increased airway pressure and decreased pulmonary shunt by increasing the alveolar to arterial pressure. However, it may result in alveolar damage, inflammation, and lung injury. There is controversy about healthy patients for lung damage due to high tidal volume, and it is said that surgery leads to the inflammation of the lung parenchyma and lung injury. As a result, the use of low tidal volumes has been considered in many studies. Regarding the evidence, ventilation with low tidal volumes, especially in patients with previous lung injury, is more appropriate and associated with less respiratory complications. In addition, using low tidal volumes and PEEP has a significant influence on weaning patient from the ventilator as soon as possible.

High tidal volume leads to increased dead space by elevating the alveolar to arterial pressure ratio. Additionally, the reduction of tidal volume results in increased pulmonary shunt by alveolar coalescence and atelectasis. This study was conducted to compare changes in pulmonary shunt and physiologic dead space between 2 groups of patients with major abdominal surgeries and ventilated by the tidal volumes of 6 mL/kg and 8 mL/kg with and without PEEP, respectively.

Methods

In this randomized clinical trial, a total of 36 patients who were candidates for nonlaparascopic upper abdominal cancer surgery were enrolled after obtaining the approval from the ethics committee of Mashhad Medical University (No. 940155). The patients were 20 and 65 years old with the American Society of Anesthesiologists physical status I and II (ASA). The patients with chronic pulmonary diseases (eg, asthma and chronic obstructive pulmonary disease), upper and lower respiratory infection, heart diseases, hepatic failure, renal failure, previous lung surgery, and thoracic surgeries were excluded from the study.

After obtaining a written consent, the patients were randomly assigned into 2 groups of A and B using the sealed envelope system. In operation room, the patients were monitored for electrocardiography, noninvasive blood pressure, heart rate, and pulse oximetry after inserting an intravenous catheter. Firstly, 1 to 2 mg of midazolam and 200 cc to 250 cc of normal saline were injected before the induction of general anesthesia.

After local infiltration of 1% lidocaine, the left radial artery puncture was performed with an appropriate catheter for invasive blood pressure monitoring and gasometrical evaluation. The patients were given 4 µg/kg fentanyl, 0.5 mg/kg atracurium, and 2 mg/kg propofol, and were ventilated using a bag valve mask (with the ventilation rate of 8-10 times per minute). Maintenance of anesthesia was performed by propofol infusion 100-150 µg/kg/min, fentanyl 1 mg/kg every half hour and O_2-N_2O 50%. After 2 minutes and jaw relaxation, the patient was intubated and after confirmation of the tracheal tube location was ventilated by anesthesia machine Drager Fabius Plus. Central venous catheter was inserted via internal jugular vein, and then it was fixed after passing 12 to 15 cm and before ECG dysrhythmia.

After intubation and prior to the ventilation, arterial and venous blood gas samples were taken from arterial line and the internal jugular vein, respectively, and vital signs were recorded. Then, the patients in the group TV8 were ventilated with the tidal volume of 8 mg/kg and respiratory rate (RR) of 10 breaths/min without PEEP, while the TV6 group received the tidal volume of 6 mL/kg with the RR of 12 breaths/min with PEEP (5 cm H_2O). In this study, the ideal body weight was used to calculate the required tidal volume. The upper abdomen surgeries were performed through a midline incision from the xiphoid to the umbilicus, and the patients" position was supine during surgery.

Intraoperative at first and every half an hour, various variables, including respiratory rate, expiratory tidal volume, peak and plateau pressure, and hemodynamic variables (heart rate and blood pressure), were recorded. Arterial and venous blood gas sampling was performed again after 2 hours. After the initiation of ventilation, the RR was adjusted to end-tidal CO_2 = 35-40 mmHg by mainstream capnogram. The inspiration-to-expiration ratio was 1:2. Phenylephrine infusion and fluid were administered in case of the systolic blood pressure (SBP) less than 90. On the other hand, in case of the SBP>160, the patients received labetalol or nitroglycerin. The blood pressure and heart rate of the patients were monitored during treatment. Saline 0.9% was infused on maintenance, deficit, and third lost rule. Packed cell was transfused for maintaining the hematocrit more than 27% to 30%. If SpO_2 decreased, at first recruitment maneuver was given. Then, if the O_2 saturation was not improved, the PEEP was increased, and the tidal volume was changed, and also the patient was excluded from the study.

The patients' body weight was calculated considering their height and following equations (depending on the weight and sex).

[Weight (male)= (length (cm)×0.9)-88, weight (female)= (length (cm)×0.9)-92].

Moreover, pulmonary shunt was measured using fol-

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lowing equation and FiO_2 = 50%; (Pulmonary shunt =1-arterial oxygen saturation/1-venous oxygen saturation [1-SaO2/1-SvO2]). In addition, the dead space-to-tidal volume was computed using the following equation: $VD/VT=PaCO_2–PetCO_2/PaCO_2$(a=arterial, et=end tidal).

Statistical Analysis

The sample size was considered to be 36 regarding the prevalence of atelectasis (90%) and its 40% reduction by the power of 90% (β=0.1) and α=0.05. The participants were divided into 2 groups (18 patients per group) (8). Data analysis was performed using t test (for parametric variables including age, weight, and length), chi-square test (for nonparametric variables such as gender), and repeated measures analysis of variance (for airway pressure, blood oxygen saturation, pulmonary shunt, and alveolar dead space) with SPSS software, version 16 (SPPS Inc). The relationship of demographic data and changes in pulmonary shunt and dead space was assessed using parametric and nonparametric regression models. In addition, normality was tested using Kolmogorov-Smirnov test. In all the measurements, P value less than .05 were considered statistically significant.

Results

There was no significant difference between the groups for patients' demographic data and hemodynamic parameters (blood pressure, heart rate, and respiratory rate) prior to the induction of anesthesia (Table 1). The primary targets were pulmonary shunt and alveolar dead space, and hemodynamic and respiratory changes were considered secondary targets.

Pulmonary Shunt

At the beginning of the study, the amounts of pulmonary shunt were 13.5±0.1% and 18.6±0.2% in the groups TV6 and TV8, respectively, which represented no statistically significant difference between these groups (p=0.132; power=0.671). At the end of the study, the amount of shunt decreased in both groups after 2 hours and reached to 12.7±0.1% and 18.4±0.2% in the groups TV6 and TV8, respectively (Fig. 1). Therefore, no significant difference was observed between the groups (p=0.284; power=0.748). Additionally, there was no significant difference in the amount of pulmonary shunt before and after the study, which means that there were similar changes in pulmonary shunt in each group (p=0.262; power=0.722).

Alveolar Dead Space

In the present study, dead space to tidal volume ratios were 0.25±0.2 and 0.14±0.1 in the groups TV6 and TV8, respectively, which showed no significant difference between the groups (p=0.163; power=.821). Moreover, at the end of the study, these ratios were 0.23±0.11 and 0.16±0.1 in the TV6 and TV8 groups, respectively. Again, there was no significant difference between these groups (p=0.271; power=0.635). In this study, the volume of dead space slightly increased in the group TV8, while it decreased in the TV6 group. However, no significant difference was observed between the groups (p=0.075; power=0.782). Although there was no significant difference, the volume of dead space in group A was more than in group B (Fig. 2). Despite the respiratory rate change (for EtCO2 preservation), the alveolar dead space was not different between the 2 groups.

Airway Pressure

The peak airway pressures were 12.5±4.3 mmHg and 15.7±3.9 mmHg in the groups TV6 and TV8, respectively, which demonstrated a significant difference between the groups (p=0.024; power=0.654). Furthermore, in this study, the peak airway pressure of the group TV8 was significantly higher than the other group. At the initiation of the study, the plateau pressures of the patients in groups TV6 and TV8 were 10.0±4.3 mmHg and 11.9±4.6 mmHg, respectively. Accordingly, there was no significant difference between the groups considering plateau pressure (p=0.181; power=0.582). In addition, no significant difference was observed between the groups regarding the plateau pressure during the study (Fig. 3).

Respiratory Rate

At first, the patients in the group TV8 and TV6 were ventilated with the RR of 10 breaths/min and 12 breaths/min, respectively. Additionally, the end-tidal CO_2 concentration was maintained at 35 mmHg 40 mmHg by changing the RR. In the current study, the mean RRs in the group TV6 and TV8 increased to 14.23 and 11.23, respectively. These changes were significant 60, 90, and 120 minutes after the initiation of the study (p=0.015; p=0.011; p=0.001, respectively).

Systolic Blood Pressure

SBP in patients at the beginning of the study was similar in the 2 groups; however, it steadily declined in the patients of group TV6. Moreover, the blood pressure firstly

Table 1. Preoperative demographic and hemodynamic parameters

Demographic parameters	TV6 group	TV8 group	P-value	Power
Age (y)	62.2±14.9	60±15.1	0.641	0.622
Gender	10/8	9/9	0.513	0.576
Weight (kg)	59.7±11.5	64.5±13.6	0.245	0.740
Height (cm)	164.5±9.6	164.4±9.3	0.982	0.549
Heart rate (pulse/min)	87.06±23.52	81.28±19.69	0.432	0.685
Respiratory rate (breaths/min)	19.06±4.81	18.47 ±6.02	0.761	0.602
Systolic blood pressure (mmHg)	133.89±17.88	128.94±36.62	0.613	0.636
Diastolic blood pressure (mmHg)	78.56±9.25	83.50±14.80	0.244	0.749
Oxygen saturation (%)	97.06±2.36	96.00±5.10	0.431	0.600

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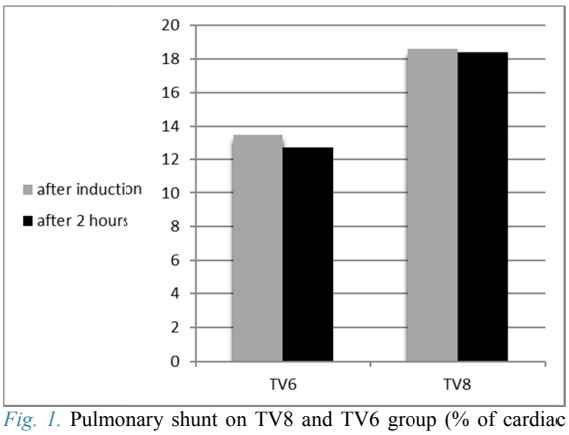

Fig. 1. Pulmonary shunt on TV8 and TV6 group (% of cardiac output). There was no significant difference between and within groups

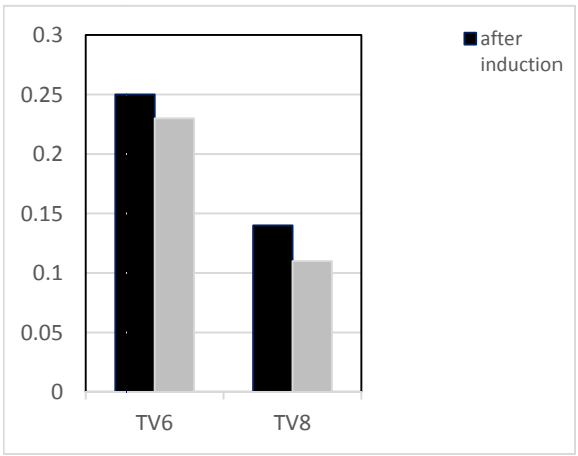

Fig. 2. Ratio of dead space over tidal volume (V_E/V_T %) at the beginning and end of study. There was no significant difference between and within groups.

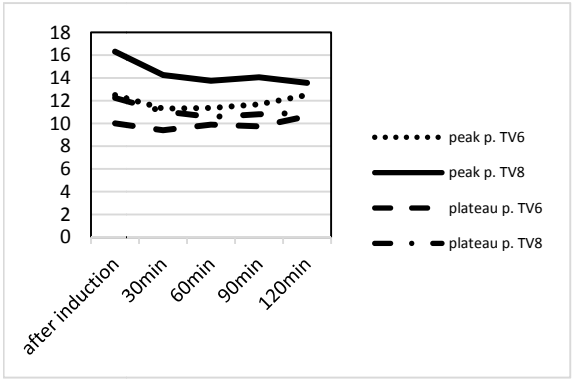

Figure 3. The changes of peak and plateau airway pressures during study (mmHg). There was a significant difference for peak pressure between groups (P=0.02), and no significant difference for plateau pressure (P=0.18).

raised in the group TV8 and then returned to the initial level. In the last half-hour of the study, the difference in the SBP in the 2 groups was significant; furthermore, there was a further decrease in the group TV6. Three patients in the group TV6 and 1 patient in the group A received ephedrine (p=0.742, power=0.92%). Conversely, nitroglycerin and labetalol were administered to 8 patients in the group TV8 and 4 patients in group TV6 (p=0.113, power=0.691).

Arterial and Peripheral Oxygen Saturation

In this study, 5 patients in the group TV6 and 2 patients in the group TV8 experienced hypoxemia. Nonetheless, all of them were treated by using alveolar recruitment maneuver. There was no significant difference between the groups in this regard (p=0.245, power=0.653).

Furthermore, the arterial oxygen saturation in group TV6 was lower than the other group at both initiation (P_1) and end of the study (P_2). This difference was clinically clear, but not statistically significant (P_1= .371, P_2=.432).

Discussion

This study was conducted on 36 patients, 18 of whom were ventilated by the tidal volume of 8 ml/kg without PEEP (TV8), while the others received the tidal volume of 6 ml/kg with 5 mmHg PEEP (TV6). Considering the results, the plateau pressure was similar in both groups, and peak airway pressure was lower on TV6. In addition, no significant difference was observed between the groups regarding the amount of pulmonary shunt and volume of dead space.

Ventilation strategy using low tidal volumes may increase the risk of atelectasis (15). According to the literature, the use of this strategy leads to less postoperative respiratory complications as well as improves gas exchange and lung mechanics (16-18). The results of another study on trauma patients who were mechanically ventilated for more than 5 hours, demonstrated no significant difference between patients ventilated by the tidal volume of 8 mL/kg and 10 mL/kg (19).

Also, in a healthy person, the amount of pulmonary shunt is about 4% to 5%, which increases in lying position. During anesthesia, pulmonary shunt increases due to mechanical ventilation, lying position, anesthesia induction, the use of muscle relaxants, reduced functional residual lung capacity, and alveolar atelectasia. According to the results obtained from the study conducted by Maslow, atelectasis was less prevalent in the patients ventilated with high tidal volumes (20).

ARDS Net group who conducted several trials in patients with ARDS, suggested placing these patients on ventilation with low tidal volumes. The low tidal volumes decrease the rate of lung injury and increase the survival in these patients. However, there is need for caution when this strategy is used for patients with healthy lungs because it might be associated with the development of atelectasis (21).

In another study that compared tidal volumes of 5 mL/kg and 7 mL/kg, it was indicated that the rates of atelectasis and acute lung injury were lower in the lower tidal volumes (22). On the other hand, a new study demonstrated that the lower tidal volume is associated with the development of internal PEEP and plays a protective role by alveolar recruitment. The use of the low tidal volume strategy is not recommended in the patients who underwent anesthesia because it could encourage an increase in atelectasis, especially if PEEP or alveolar recruitment ma-

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neuver is not applied (23).

In addition, the intensive care unit length of stay and morbidity were less in the patients ventilated with lower tidal volumes. In the present study, we compared 2 tidal volumes of 6 mL/kg and 8 mL/kg. Although there was no significant statistical difference between the groups, the pulmonary shunt in the group TV6 was less than group TV8. In our study, pulmonary shunt increased following anesthesia, about 13.5% to 18.6% in the 2 groups. The less increase of shunt in group TV6 may be due to the use of PEEP. Also, the higher volume could not prevent the amount of pulmonary shunt and maybe atelectasis. Although in our study, hypoxia is more on TV6 group clinically, not statistically, hypoxia was not long-lasting and was solved with recruitment maneuver.

In the group B, the peak airway pressure was less than the other group during evaluation (2 hours). However, no significant difference was observed between the groups in terms of plateau pressure. The peak pressure is proportional to the airway resistance; nevertheless, the plateau pressure is associated with pulmonary and alveolar compliance and does not change with increasing volume. Another study was performed to compare 2 tidal volumes of 5 mL/kg and 10 mL/kg. According to the results of the mentioned study, in most cases, the plateau and peak airway pressures were higher in the group ventilated by high tidal volume. Nonetheless, no plateau pressure more than 30 cmH_2O was observed (20). Petrucci in his study indicated that with the plateau pressure maintained at less than 31 cmH_2O, there was no difference between the patients placed on high and low tidal volume ventilation strategies considering their survival (24). In another study conducted by Midchefer on patients with esophageal cancer, the tidal volumes of 5 mL/kg and 9 mL/kg were compared. Regarding the results of the mentioned study, the airway pressure was lower in the group ventilated by lower tidal volume (25). In addition, Yang compared 2 tidal volumes of 6 mL/kg and 10 mL/kg and demonstrated that the airway pressure was lower in the group that underwent ventilation with lower tidal volume (26).

Another topic evaluated in this study was alveolar dead space, which increases due to reduced pulmonary blood flow as a result of arterial obstruction as well as hypotension or shock. In the present study, we monitored the blood pressure; therefore, the alveolar dead space did not change with changing the tidal volume. In a study on the animal model, the dead space did not differ in the tidal volumes of 10, 12, and 15 L/min (27). The results of another study performed on patients with ARDS demonstrated a significant difference between the mortality rate and alveolar dead space (28). Similarly, in a multicentric study, an increase of up to 60% of dead space caused a significant increase in mortality rate (29). The high tidal volume group leads to alveolar expansion, stress, inflammation, and repeated closure of dependent regions. Regarding the results of CAI study, there was no significant difference between the patients ventilated by the tidal volume of 6 L/min and those ventilated by 10 L/min regarding the alveolar dead space (30). In our study, after 2 hours, the alveolar dead space was not significantly different between the 2 groups. Also, in the study of Hassani et al, the change in tidal volume had no effect on the alveolar dead space (31). In group B, the alveolar dead space was less than group A clinically, but it was not statistically significant. Increasing the alveolar dead space in group A is likely to be due to the increased tidal volume and airway pressure.

The limitations of this study included the low sample size and difficulty for evaluation of atelectasis by CT scan.

Conclusion

In the present study, the comparison of blood pressure, pulmonary shunt, and alveolar dead space did not show any significant difference between tidal volume 6 mL/kg with low PEEP and tidal volume 8 mL/kg without PEEP. The only difference in this study was the peak airway pressure, which was higher in the tidal volume 8 mL/kg group compared to the other group. Regarding the results, the use of the tidal volume of 6 mL/kg with the PEEP of 5 mmHg is similar in hemodynamic and pulmonary changes, and if there is a need for lower airway pressure in patients with obstructive pulmonary diseases, it would be possible to use the tidal volume of 6 mL/kg.

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Conflict of Interests

The authors declare that they have no competing interests.

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