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Comparison of Dynamic and Static Compliance in Two Ventilation Methods with Tidal Volume of 6 and 10 ml/kg: Randomized Clinical Trial

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Abstract

Background: Pulmonary compliance is an important lung factor and is affected by tidal volume. In this study, static and dynamic compliance with tidal volumes of 6 and 10 ml/kg have been evaluated in patients undergoing abdominal cancer surgery.

Methods: This randomized clinical trial was conducted on 50 patients who were candidate for abdominal cancer surgery. This study was done in patients aged 20-65 years without chronic diseases. After induction of anesthesia, the first group was ventilated with a tidal volume of 10 ml/kg and 8 breaths/minute, and also the second group was ventilated with a tidal volume of 6 mL/kg and 14 breaths/minute. From the beginning and every 15 minutes, expiratory tidal volume, peak and plateau airway pressure, heart rate and blood pressure were measured for two hours. The data was analyzed with SPSS v.20 and $P < 0.05$ was meaningful.

Results: There was no significant difference between the two groups for demographic characteristics. There was no significant difference between the two groups in the dynamic and static compliance of the patients during the study. However, the static compliance decreased in the 6 ml/kg group and increased in the 10 ml/kg group, but the difference was not statistically significant ($P = 0.32$). The peak, plateau pressure and hemodynamic parameters were the same in the two groups.

Conclusion: In general, the static and dynamic compliance was not significantly different in the two groups despite a slight decrease in the 6 ml/kg group and a slight increase in the 10 ml/kg group.

Keywords: Mechanical ventilation, Tidal volume, Dynamic compliance, Static compliance

Conflicts of Interest: None declared
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Introduction

Mechanical ventilation is the basic method of gas exchange during general anesthesia. In recent decades, high tidal volume ventilation (between 10 and 15 ml/kg), and also positive end-expiratory pressure (PEEP) have been used to prevent intraoperative atelectasis (1, 2). There are several evidence that high tidal volume, with or without low PEEP, causes lung injury, excessive alveolar expansion and ventilator-induced lung injury (3-6). Alveolar expansion can cause protein secretion, a decrease in surfactant activity, deterioration of compliance, and finally, atelectasis (7, 8). Lung protective ventilation with low tidal volume, low pulmonary pressure and also PEEP can reduce alveolar expansion and improve outcomes and pulmonary function in critically ill patients with acute respiratory distress syndrome (ARDS) (9-11). However, the studies show different results regarding the effect of low tidal volume on postoperative outcomes.

Pulmonary compliance depends on lung tissue elasticity and is proportional to lung volume and airway pressure

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↑What is "already known" in this topic:
Static and dynamic compliance were not significantly different between 6 mL/kg and 10 mL/kg tidal volumes, despite a slight decrease in static compliance with 6 mL/kg and a slight increase with 10 mL/kg.

→What this article adds:
The lower tidal volume of 6 ml/kg with low positive end-expiratory pressure (PEEP= 5cmH2O) has low changes in lung physiology (compliance}. It is a relatively good choice and will cause less postoperative pulmonary complications.

changes. Finding the appropriate tidal volume to maintain the pulmonary compliance is very important to prevent postoperative complications and reduce hospital length of stay and hospital costs (12-14).

There are few studies on the effect of tidal volumes on patients' lung compliance and lung function. Therefore, in the present study, we aimed to compare the low tidal volume (6 ml/kg) with the high tidal volume (10 ml/kg) on pulmonary compliance in abdominal cancer surgery patients.

Methods

This study is a randomized double-blinded clinical trial and approved by the Deputy Research of the Mashhad University of Medical Sciences with the number 980622. After registration in the Iranian registration center (IRCT20101130005280N35 on 2020-12-28), 50 patients aged 20-65 years old and candidates for non-laparoscopic non-hepatic gastrointestinal cancer surgery were chosen. After obtaining written informed consent, patients are divided into two equal groups (6 ml/kg and 10 ml/kg for tidal volume; as parallel trial and allocation ratio 1:1) by using an online random number table at "www.randomization.com" website by an anesthesiologist and random sealed envelopes. The 50 patients fulfilled all criteria and participated in the study. Each patient was allocated to a group using a sealed envelope by patients. The patients were blinded, but blindness for the nurse and anesthesiologist was impossible due to the ventilator parameters being clear; however, measurement was done by the anesthesia delivery system. The statistical analyzer was also blinded for grouping. Patients with chronic lung diseases such as asthma and chronic obstructive pulmonary disease (COPD), chronic heart and kidney disease, liver metastasis and high liver enzymes, previous lung surgery, and simultaneous thoracic surgery were excluded.

In the educational and general operating room, patients were monitored for electrocardiography, peripheral saturation o2, non-invasive blood pressure, and pulse rate. Midazolam 1 mg was injected, and 200 to 250 cc of saline was infused. The patients were anesthetized with fentanyl 4 µg/kg, atracurium 0.5 mg/kg and propofol 2 mg/kg. After manual ventilation with a mask, 8-10 breaths/minute and the jaws relaxation, the patients were intubated and ventilated mechanically. Then patients were divided into two equal groups. The first group was ventilated with a tidal volume of 10 ml/kg, 8 breaths/minute and PEEP=5cmH2O, and the second group was ventilated with a tidal volume of 6 ml/kg, 14 breaths/minute and PEEP =5cm H2O. The respiratory rate was adjusted by end-tidal CO2 to 30-40 Cm H2O. Anesthesia was maintained by propofol infusion 100-150 µg/kg/min and N2O-O2 1-1 L/min. To adjust for tidal volume, the ideal body weight was used based on height (cm) and gender [men = (height × 0.9) -88 and women = (height × 0.9) -92].

At the beginning and every thirteen minutes, breath rate, expiratory tidal volume, peak and plateau pressure, and also hemodynamic variables were recorded. If systolic blood pressure was less than 90 mmHg, saline was infused more, and phenylephrine was injected. If systolic blood pressure was more than 160 mmHg, 20mg labetalol or nitroglycerine was infused. The saline was calculated and injected according to the standard rule. In case of excessive bleeding, packed cells were infused for a hematocrit of 27-30%.

The primary outcomes were static and dynamic compliance that were measured at the start of mechanical ventilation and every 30 minutes to two hours and calculated with the following formulas. Dynamic compliance = tidal volume/ Ppeak-PEEP, Static compliance = tidal volume/Pplat-PEEP. The secondary outcomes were peak and plateau airway pressure that also were evaluated after intubation and mechanical ventilation beginning and every 30 minutes for two hours.

Statistical Methods

Considering the alpha error of 0.05 and the test power of 80%, and using the G*Power V3.1 software and also according to the average static compliance rate of 90 ml/cmH2O reduction of almost 30% (15) of lung static compliance (15), the sample size was calculated as 20 patients in each group. With a 20% drop, the final sample was 25 patients in each group.

After collecting the data, the data were analyzed by Spss V20 software. Age, height, and weight in the two groups were compared using a t-test. Parametric data, compliance, airway pressure, peripheral oxygen saturation, respiratory rate, heart rate and blood pressure were compared by repeated measure ANOVA test. The relationship between age, gender, weight, and height with changes in compliance was calculated by parametric and regression tests. $P < 0.05$ was considered significant.

Results

In total, 50 patients (25 in each group) participated and fulfilled the criteiria in this study with no exclusion and follow-up refusal (Figure 1). Demographic parameters of the patients, including sex, age, BMI, heart rate, breathing rate, blood pressure, and peripheral blood oxygen level, are shown in Table 1. There was no significant difference in demographic parameters between the two groups. The primary outcomes were static and dynamic compliance, and the secondary outcome was airway pressure changes.

In the 10 ml/kg group, dynamic compliance was 52.9 ± 2.7 ml/cmH_2O in the first minute and 63.8 ± 2.1 ml/cmH_2O after two hours, which was not statistically significant (P = 0.17) despite a slight increase. Also, in the 6 ml/kg group, the dynamic compliance was 60.2 ± 2.5 ml/cmH2O at the beginning and 55.2 ± 0.19 ml/cmH2O after two hours, and despite a slight decrease, the change was not significant (P = 0.18). In the comparison of the two groups, no clear change in dynamic compliance was observed during the study period (Table 2). Regarding changes in static compliance in the 10 ml/kg group, despite a brief increase in two hours from 73.7 ± 3.9 to 92.7 ± 8.5 ml/cmH_2O, the difference was not statistically significant (P = 0.32). In the 6 ml/kg group, there was a slight decrease in static compliance during the study, which was not statistically significant (P = 0.468). The two groups did not have a clear statistical difference for static compliance during the study (Table 3).

The peak airway pressure in the 6 ml/kg group only at

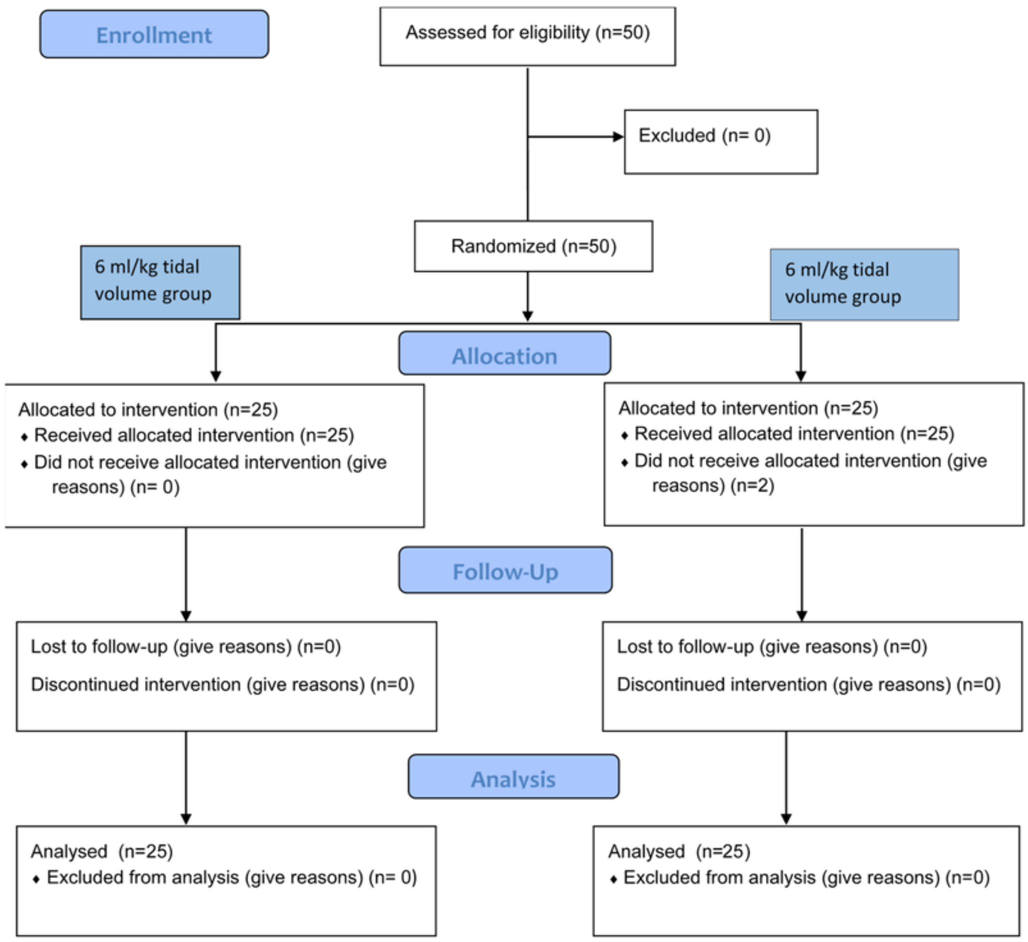

Figure 1. Consort flow diagram

Table 1. Demographic and preoperative parameters mean±sd.

Variable	10 ml/kg Group (n=25)	6 ml/kg Group (n=25)	*P*-value
Sex (M/F)	16/9	18/7	0.543
Age (year)	62.1±13,8	60.0±14.2	0.672
BMI (kg/m^2)	22.3±0.9	23.9±1.1	0.360
Heart rate	86.4±4.1	79.9±3.5	0.261
Respiratory rate	19.2±0.9	18.0±1.1	0.364
Systolic blood pressure	119.1±8.6	124.3±7.9	0.758
Diastolic blood pressure	78.1±1.7	83.2±2.6	0.153
SPO_2	97.0±0.4	96.0±0.9	0.489

minute 120 was not significantly different from the 10 ml/kg group ($P = 0.11$). At all previous moments, the peak airway pressure was significantly higher in the 10 ml/kg group. Also, in the 10 ml/kg group, the peak airway pressure was significantly reduced from minute 1 to minute 120 ($P = 0.002$). However, in the 6 ml/kg group, the peak airway pressure did not change significantly during the study ($P = 0.124$) (Table 4).

The plateau pressure was not significantly different between the two groups during the surgery. Although, in the 10 ml/kg group, the plateau pressure was statistically significantly reduced ($P = 0.006$). Of course, this change was not very clear from the clinical point of view and the plateau pressure reached 10.44±0.8 cmH_2O after two hours from 11.9±0.9 cmH_2O. In the 6 ml/kg group, the plateau pressure did not change significantly from the beginning to the end of the study ($P = 0.33$). During the study period, there was no significant change between the two groups for hemodynamics and respiratory parameters (Table 5).

Discussion

The results of the present study showed that the static compliance of patients in the 6 ml/kg group decreased during the study, and in the 10 ml/kg group, the static compliance increased slightly during the study, which was not statistically significant. There was no significant difference in the dynamic and static compliance of the patients between the two groups. Also, there was no significant difference in peak and plateau pressure between the two groups during the study.

Fotier et al. published a study about lung protective ventilation in abdominal surgeries. They showed that the use

Table 2. Intraoperative dynamic compliance mean±sd. Comparison among and between two groups by repeated measure ANOVA test.

Dynamic compliance (ml/cmH_2O)	10 ml/kg Group (n=25)	6 ml/kg Group (n=25)	P-value
Minute 1	52.9±2.7	60.25±2.5	0.330
Minute 30	61.6±1.9	70.77±4.1	0.325
Minute 60	67.59±2.8	68.75±3.5	0.891
Minute 90	62.88±2.6	61.3±2.6	0.728
Minute 120	63.83±2.1	55.27±1.9	0.139
P-value	0.172	0.181	

Table 3. Intraoperative static compliance mean±sd. Comparison among and between two groups by repeated measure ANOVA test.

Static compliance (ml/cmH_2O)	10 ml/kg Group (n=25)	6 ml/kg Group (n=25)	*P*-value
Minute 1	73.79±3.9	90.54±6.6	0.282
Minute 30	72.46±3.1	90.97±6.5	0.201
Minute 60	83.28±4.8	89.08±6.5	0.718
Minute 90	82.04±4.4	84.18±4.3	0.862
Minute 120	92.7±8.5	79.08±5.6	0.293
P-value	0.325	0.471	

Table 4. Intraoperative peak pressure mean±sd. Comparison among and between two groups by repeated measure ANOVA test.

Peak pressure (cmH_2O)	10 ml/kg Group (n=25)	6 ml/kg Group (n=25)	*P*-value
Minute 1	15.6±0.7	12.4±0.7	0.001
Minute 30	13.9±0.8	11.3±0.5	0.008
Minute 60	13.5±0.8	11.3±0.5	0.021
Minute 90	13.7±0.6	11.7±0.5	0.031
Minute 120	13.6±0.5	12.2±0.5	0.110
P-value	0.124	0.002	

Table 5. Intraoperative plateau pressure mean±sd. Comparison among and between two groups.

Plateau pressure (cmH_2O)	10 ml/kg Group (n=25)	6 ml/kg Group (n=25)	*P*-value
Minute 1	11.9±0.9	10.0±0.8	0.063
Minute 30	10.9±0.9	9.3±0.6	0.131
Minute 60	10.6±0.9	9.9±0.5	0.589
Minute 90	10.7±0.9	9.8±0.5	0.277
Minute 120	10.4±0.9	10.5±0.6	0.952
P-value	0.330	0.006	

of non-protective ventilation, especially high tidal volume with very low end-expiratory pressure (PEEP<5 cm H2O) or not using PEEP, can cause excessive alveolar expansion and lung damage associated with ventilation in patients with healthy lungs. According to such studies, low tidal volume is becoming more common day by day. However, tidal volume reduction is only one part of a multifaceted approach to lung-protective mechanical ventilation. New data show that the use of preventive lung protective ventilation using tidal volume, 6 mL/kg and PEEP= 6 cmH2O and recruitment maneuver is associated with improvement in lung function and treatment outcomes in patients undergoing abdominal surgery (16).

In a study conducted in 2010 by Weingarten et al., patients were compared between tidal volumes of 6 and 10 ml/kg. They showed a 36% increase in the compliance of patients with a tidal volume of 6 ml/kg compared to a tidal volume of 10 ml/kg. Also, airway resistance in this group has decreased by 36%. Also, they showed that a tidal volume of 6 ml/kg is more successful in maintaining pulmonary compliance, but in our study, there was no change in static and dynamic compliance between the 6 and 10 ml/kg groups (15).

In the other study in 2021, two volumes of 9 and 7 ml/kg were compared in patients. In this study, contrary to our study, after 40 minutes, the compliance of patients in the 7 ml/kg group was significantly higher than the 9 ml/kg group. Also, postoperative complications and radiographic changes were less in the group with lower circulating volume (17).

In the study of Siverganini et al., the tidal volume of 7 ml/kg was compared with 9 ml/kg in patients who had open abdominal surgery. In this study, similar to our study, the compliance of patients in the two groups was not significantly different from each other. In this study, better lung tests, fewer changes in chest radiography, and higher arterial oxygen levels were reported in patients who used a tidal volume of 6 ml/kg. Also, lung infections were significantly less in these patients, but it was not investigated in our study (18). In the other study, on patients who underwent general anesthesia for laparoscopy, the tidal volume was compared between 6 and 12 ml/kg. In this study, there was no significant difference between pulmonary tests, pulmonary complications, length of hospitalization and death in the two groups. In this study, compliance changes in the 6 ml/kg group had an increasing trend, while in the 12 ml/kg group, these changes had a decreasing trend (19). This finding was similar to our study. Although the changes between the two groups and in each group were not statistically different, there was a slight increase in the 6 ml/kg group and a slight increase in the 10 ml/kg compliance. Also, in another study, comparison between tidal volumes of 6 and 10 ml/kg, lower tidal volume needs less for re-ventilation (P = 0.020). Although, there was no significant difference in lung compliance between the two groups (10).

In general, with the results of the studies and despite the differences, it is not possible to determine which tidal volume is appropriate. These differences can be due to the operating conditions of the patients, underlying diseases, and the different tidal volumes that have been used.

One of the most important limitations of the present study was that it coincided with the period of the COVID-19 pandemic. This problem limited access to samples. Thus, the small sample size is one of the limitations of the present study. Also, the lack of examination of postoperative complications and the length of hospital stay were among the limitations of the present study.

Conclusion

The results of the present study show that the static and dynamic compliance of the patients were not different in the two groups. However, static compliance increase slightly in the 6 ml/kg group and also decrease slightly in the 10 ml/kg group. Also, the peak airway pressure was significantly higher in the 10 ml/kg group.

Authors' Contributions

Mehryar Taghavi Gilani: design of the work; Alireza Bameshki: analysis and interpretation of data; Majid Razavi: drafted the work and corresponder; Ghorbanali Sadeghzadeh: acquisition of data.

Ethical Considerations

This study was taken from thesis no: 980622 and the local ethics committee with the number IRMUMS.MEDICAL. REC1399.519.

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Conflict of Interests

The authors declare that they have no competing interests.

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