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Comparison of Low vs. High Tidal Volumes in One-Lung Ventilation: Impacts on Respiratory Function and Clinical Outcomes during Thoracic Surgery

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ABSTRACT

Background: One-lung ventilation (OLV) is a commonly used technique in thoracic surgery that poses challenges to respiratory function.

Objective: To evaluate the impact of low vs. high tidal volumes during one-lung ventilation on postoperative pulmonary complications, respiratory function, length of ICU and hospital stay, and mortality in thoracic surgery patients.

Methods: A prospective observational cohort study was conducted at Fatima Jinnah Institute of Chest Diseases Quetta from April 2024 to April 2025 with 245 adult patients undergoing elective thoracic surgery requiring OLV. Patients were divided into two groups: Group A (low tidal volume) and Group B (high tidal volume). Postoperative outcomes, including pulmonary complications, arterial blood gas (ABG) measurements, lung compliance, ICU and hospital stay duration, and 30-day mortality were assessed.

Results: The incidence of postoperative complications, including atelectasis (21% vs. 34%), pneumonia (12% vs. 20%), and ARDS (6% vs. 10%), was significantly lower in Group A (low tidal volume). PaO_2/FiO_2 ratios at 24 hours were higher in Group A (275 ± 48) compared to Group B (245 ± 55, $p = 0.01$), indicating better oxygenation. Lung compliance at 24 hours was better in Group A (42.3 ± 7.8) compared to Group B (39.1 ± 6.5). The length of ICU stay and total hospital stay were significantly shorter in Group A (2.4 days and 7.6 days, respectively) compared to Group B (3.1 days and 8.2 days, respectively). Mortality rates were low in both groups (0.8% in Group A vs. 1.6% in Group B), with no significant difference ($p = 0.47$).

Conclusion: It is concluded that low tidal volume ventilation during one-lung ventilation in thoracic surgery patients is associated with reduced postoperative pulmonary complications, better respiratory function, and shorter ICU and hospital stays..

Keywords: *One-lung ventilation, tidal volume, thoracic surgery, pulmonary complications, respiratory function*

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1. INTRODUCTION

In thoracic surgery, one-lung ventilation (OLV) is a vital technique that facilitates optimal surgical exposure by isolating and ventilating a single lung, while the other lung is collapsed. This is commonly required in procedures such as lung resections, esophagectomies, and mediastinal surgeries [1]. However, OLV presents significant challenges to respiratory physiology, including the reduction of pulmonary gas exchange and the risk of ventilator-induced lung injury (VILI).

Consequently, managing ventilation parameters such as tidal

volume (TV) during OLV is crucial to minimizing complications, ensuring optimal oxygenation, and preventing further damage to the lung tissue [2]. The question of whether low or high tidal volumes provide the best outcomes during OLV remains a topic of intense debate. Traditionally, tidal volumes during mechanical ventilation have been set at 8–10 mL/kg of ideal body weight to ensure adequate ventilation and oxygenation [3]. However, this practice has been questioned, especially with the growing evidence linking higher tidal volumes to an increased risk of VILI. VILI is primarily caused by overdistention of the alveoli, leading to inflammation, oxidative stress, and further lung injury, which can result in postoperative complications such as acute respiratory distress syndrome (ARDS) [4]. As a result, a shift toward lower tidal volumes (typically 4–6 mL/kg of predicted body weight) has gained support in recent years, especially in patients with pre-existing pulmonary conditions [5].

Research investigating the impact of tidal volume on clinical outcomes during OLV has produced conflicting findings. Some studies have shown that lower tidal volumes may reduce the incidence of postoperative pulmonary complications, such as atelectasis, hypoxemia, and pneumonia [6]. Additionally, lower tidal volumes have been associated with improved lung compliance and reduced inflammation in animal models of acute lung injury. For example, a study by El Tahan et al. (2023) concluded that the use of lower tidal volumes (4–7 mL/kg) during OLV significantly improved postoperative gas exchange and reduced the risk of complications such as pneumonia and ARDS [7]. In contrast, another large multicenter study by Braïk et al. (2025) reported no significant difference in postoperative respiratory complications when comparing low and high tidal volume strategies, although low tidal volumes were associated with a higher incidence of postoperative atrial fibrillation [8]. The rationale behind using low tidal volumes during OLV is based on the concept of lung protective ventilation, which aims to minimize the mechanical injury to the lungs during ventilation. Low tidal volume ventilation has been shown to reduce the risks of barotrauma and volutrauma, both of which can exacerbate lung injury and increase the length of hospital stay [9]. On the other hand, high tidal volumes might be beneficial for ensuring adequate oxygenation and carbon dioxide removal in patients who may be at risk of hypoventilation or inadequate ventilation due to compromised pulmonary function. As such, high tidal volumes are often used in cases where maintaining normocapnia and oxygenation is critical, such as in patients undergoing major thoracic procedures [10]. Several factors may influence the choice between low and high tidal volumes during OLV. One such factor is the use of recruitment maneuvers, which help open up collapsed alveoli, thereby improving oxygenation and lung compliance. The application of positive end-expiratory pressure (PEEP) also plays a critical role in maintaining alveolar stability and preventing atelectasis during OLV. In combination with tidal volume adjustments, these strategies can significantly alter the outcomes of OLV, making it difficult to isolate the specific effects of tidal volume alone. Moreover, the optimal tidal volume may differ based on the patient's underlying respiratory function, with those suffering from chronic obstructive pulmonary disease (COPD) or asthma possibly benefiting more from low tidal volumes [11].

2. OBJECTIVE

This study aimed to compare the effects of low (4-6 mL/kg) versus high (8-10 mL/kg) tidal volumes during OLV on respiratory function and clinical outcomes in thoracic surgery patients.

3. METHODOLOGY

This study was a prospective, observational cohort study conducted Fatima Jinnah Institute of Chest Diseases Quetta from April 2024 to April 2025. The study followed a comparative design, where patients were stratified into two groups based on the tidal volume settings during OLV: a low tidal volume group (4-6 mL/kg) and a high tidal volume group (8-10 mL/kg). A total of 245 adult patients undergoing thoracic surgery requiring one-lung ventilation were included in the study. The sample size was calculated using the WHO sample size calculator, assuming a power of 80%, a confidence level of 95%, and a margin of error of 5%. The anticipated prevalence of postoperative pulmonary complications was 20%, with an expected effect size of 10%, justifying a sample size of 245 patients for adequate statistical power.

Inclusion Criteria

Adult patients (≥18 years) undergoing elective thoracic surgery that required one-lung ventilation.

Patients with an American Society of Anesthesiologists (ASA) physical status classification of I-III.

Patients who were able to tolerate mechanical ventilation and had no contraindications to the use of OLV.

Patients who provided informed consent to participate in the study.

Exclusion Criteria

Patients with a history of severe obstructive or restrictive pulmonary diseases (e.g., severe COPD, pulmonary fibrosis).

Patients with active infections (e.g., pneumonia, tuberculosis).

Patients who required emergent thoracic surgery.

Patients with cardiovascular instability or known arrhythmias that would interfere with the safe conduct of anesthesia.

Patients with significant anatomical variations or contraindications for OLV.

Pregnant patients.

Data collection

Data were collected from various sources, including preoperative assessments, intraoperative monitoring, and postoperative evaluations. Preoperative data included demographic information such as age, sex, BMI, and medical comorbidities like hypertension and diabetes. Intraoperative data included details on the anesthesia management, such as the anesthetic agents used, the mode of ventilation, and the tidal volume settings during OLV. The study divided patients into two groups based on the tidal volume settings used during one-lung ventilation. Group A, the low tidal volume group, received 4–6 mL/kg of ideal body weight, while Group B, the high tidal volume group, was ventilated with 8–10 mL/kg. The tidal volume settings were adjusted by the anesthesiologists based on the patient's clinical condition. Recruitment maneuvers and positive end-expiratory pressure (PEEP) were applied consistently across both groups to minimize atelectasis and optimize oxygenation during OLV. Postoperative data focused on clinical outcomes, including arterial blood gas (ABG) measurements at 6, 12, and 24 hours postoperatively, lung compliance, and the incidence of pulmonary complications such as atelectasis, pneumonia, and acute respiratory distress syndrome (ARDS). Additionally, data on the length of ICU stay, total hospital stay, and mortality were also recorded. The primary outcome of the study was the incidence of postoperative pulmonary complications, including atelectasis, pneumonia, and ARDS. Secondary outcomes included changes in respiratory function as indicated by ABG values and lung compliance, the length of ICU stay, total hospital stay, and the occurrence of other clinical complications such as arrhythmias and infections. Mortality rates within 30 days post-surgery were also tracked.

Statistical Analysis

Statistical analysis was carried out using SPSS version 26. Descriptive statistics were used to summarize the baseline characteristics of the patient population. Continuous variables, such as age and BMI, were reported as mean ± standard deviation, while categorical variables, such as gender and complications, were presented as frequencies and percentages. The comparison of continuous variables between the two groups was performed using independent t-tests, while chi-square tests were used for categorical variables. A p-value of less than 0.05 was considered statistically significant.

4. RESULTS

Data were collected from 245 patients. There was no significant difference in age between the two groups, with Group A having a mean age of 63.2 ± 8.5 years and Group B having a mean age of 64.0 ± 7.8 years ($p = 0.68$). Both groups had a similar gender distribution, with 60% of male patients in each group, indicating a comparable gender ratio. Body Mass Index (BMI) was also similar between the groups, with Group A having a mean BMI of 27.5 ± 3.4 kg/m² and Group B having a mean BMI of 28.0 ± 3.5 kg/m², and no significant difference was observed ($p = 0.54$). The prevalence of hypertension was slightly higher in Group B (80%) compared to Group A (78%), but this difference was not statistically significant. Similarly, the incidence of diabetes was also comparable between the groups (43% in Group A and 45% in Group B). The mean duration of OLV was almost identical between the groups, with Group A having 98.3 ± 24.2 minutes and Group B having 99.5 ± 25.7 minutes ($p = 0.81$), suggesting that the duration of surgery did not differ significantly based on tidal volume settings. Tidal volume was significantly different between the two groups, with Group A receiving a mean tidal volume of 5.2 ± 0.8 mL/kg and Group B receiving 9.1 ± 0.9 mL/kg ($p < 0.001$). This highlights the intended difference in ventilation strategies. The PEEP values were similar between the two groups, with Group A having a mean of 5.2 ± 1.1 cm H_2O and Group B having 5.1 ± 1.0 cm H_2O ($p = 0.72$), indicating that PEEP was consistently applied across both groups.

Table 1. Demographic and Clinical Characteristics

Variable	Group A (Low Tidal Volume)	Group B (High Tidal Volume)	p-value
Age (years)	63.2 ± 8.5	64.0 ± 7.8	0.68
Gender (Male)	60%	60%	-
BMI (kg/m²)	27.5 ± 3.4	28.0 ± 3.5	0.54
Hypertension (%)	78%	80%	-
Diabetes (%)	43%	45%	-

Intraoperative Parameters			
Duration of OLV (minutes)	98.3 ± 24.2	99.5 ± 25.7	0.81
Tidal Volume (mL/kg)	5.2 ± 0.8	9.1 ± 0.9	<0.001
PEEP (cm H_2O)	5.2 ± 1.1	5.1 ± 1.0	0.72

The incidence of atelectasis was 21% in Group A and 34% in Group B, with a statistically significant difference ($p = 0.03$). Pneumonia occurred in 12% of Group A patients, while 20% of Group B patients developed pneumonia ($p = 0.04$). The incidence of ARDS was also higher in Group B (10%) compared to Group A (6%), with a significant difference ($p = 0.02$). In terms of respiratory function, the PaO2/FiO2 ratio at 24 hours postoperatively was significantly higher in the low tidal volume group (275 ± 48) compared to the high tidal volume group (245 ± 55), indicating better oxygenation in Group A ($p = 0.01$). Lung compliance, which is an indicator of lung elasticity and function, was slightly higher in Group A (42.3 ± 7.8 mL/cm H_2O) compared to Group B (39.1 ± 6.5 mL/cm H_2O), although this difference was not statistically significant ($p = 0.06$).

Table 2. Postoperative Pulmonary Complications

Complication	**Group A (Low Tidal Volume)**	**Group B (High Tidal Volume)**	**p-value**
Atelectasis	21%	34%	0.03
Pneumonia	12%	20%	0.04
ARDS	6%	10%	0.02
PaO2/FiO2 Ratio at 24h	275 ± 48	245 ± 55	0.01
Lung Compliance at 24h (mL/cm H_2O)	42.3 ± 7.8	39.1 ± 6.5	0.06

The length of stay in both the ICU and hospital was significantly shorter in the low tidal volume group. The median ICU stay was 2.4 days (IQR: 2–3) for Group A, compared to 3.1 days (IQR: 2–4) for Group B, with a statistically significant difference ($p = 0.03$). Similarly, the total hospital stay was shorter in Group A, with an average of 7.6 ± 1.2 days, compared to 8.2 ± 1.4 days in Group B ($p = 0.04$). Arrhythmias occurred in 9% of Group A patients and 15% of Group B patients ($p = 0.08$). Similarly, postoperative infections were seen in 12% of Group A patients and 16% of Group B patients ($p = 0.14$), though neither of these differences were significant. The 30-day mortality rate was low in both groups, with 0.8% of patients in Group A and 1.6% in Group B dying within 30 days post-surgery. This difference was not statistically significant ($p = 0.47$).

Table 3. Length of ICU and Hospital Stay

Variable	**Group A (Low Tidal Volume)**	**Group B (High Tidal Volume)**	**p-value**
ICU Stay (days)	2.4 (IQR: 2–3)	3.1 (IQR: 2–4)	0.03
Total Hospital Stay (days)	7.6 ± 1.2	8.2 ± 1.4	0.04
Complications			
Arrhythmias	9%	15%	0.08
Postoperative Infections	12%	16%	0.14
30-Day Mortality	0.8%	1.6%	0.47

5. DISCUSSION

The aim of this study was to compare the effects of low versus high tidal volumes during one-lung ventilation (OLV) on respiratory function and clinical outcomes in patients undergoing thoracic surgery. The findings provide valuable insights into the optimal tidal volume strategy for minimizing postoperative pulmonary complications and improving patient recovery. The results of this study indicated a significant reduction in the incidence of postoperative pulmonary complications in the low tidal volume group (Group A). Specifically, the incidence of atelectasis, pneumonia, and acute respiratory distress syndrome (ARDS) was lower in Group A compared to Group B. This supports the growing body of evidence suggesting that low tidal volume ventilation is beneficial in reducing ventilator-induced lung injury (VILI), particularly in high-risk surgical patients. Previous research has demonstrated that lower tidal volumes, typically ranging from 4–6 mL/kg of ideal body weight, are associated with reduced rates of VILI and better pulmonary outcomes, including improved oxygenation and reduced inflammatory response [12][13]. The incidence of atelectasis was notably higher in Group B, the high tidal volume group, which is consistent with the well-documented association between high tidal volumes and overdistension of the lungs. High tidal volumes may lead to alveolar damage and subsequent collapse, further exacerbating pulmonary dysfunction. This aligns with findings from previous studies, which have shown that excessive lung distension during mechanical ventilation can cause mechanical trauma to the alveolar-capillary barrier, leading to atelectasis and ARDS. The improved respiratory function in the low tidal volume group was further evidenced by the significantly higher PaO2/FiO2 ratio at 24 hours postoperatively in Group A compared to Group B. A higher PaO2/FiO2 ratio is indicative of better oxygenation, which is crucial for recovery after major surgery. Previous research has similarly found that low tidal volume ventilation results in better gas exchange and less postoperative hypoxemia, which is a known contributor to poor clinical outcomes following thoracic surgery [14][15]. The low tidal volume group also had a shorter length of ICU stay and total hospital stay, which can be attributed to fewer pulmonary complications and better overall respiratory function. This finding underscores the potential economic and clinical benefits of using low tidal volume strategies in thoracic surgery [16]. Shorter ICU and hospital stays are critical in reducing healthcare costs and improving patient throughput, which is an important consideration in managing surgical patient populations. The incidence of arrhythmias, particularly postoperative atrial fibrillation, was slightly higher in the high tidal volume group, though this difference was not statistically significant. This finding warrants further investigation, as previous studies have linked postoperative arrhythmias to ventilator management strategies, with some evidence suggesting that mechanical ventilation parameters such as tidal volume can influence autonomic regulation and contribute to the development of arrhythmia.

6. LIMITATIONS AND FUTURE DIRECTIONS

While this study provides valuable insights into the effects of tidal volume on OLV outcomes, several limitations need to be acknowledged. First, as an observational study, there may have been confounding factors that influenced the results, such as variations in anesthesia techniques, the use of recruitment maneuvers, or PEEP settings. Randomized controlled trials are needed to further elucidate the causal relationship between tidal volume and postoperative outcomes. Additionally, while the sample size was calculated to achieve adequate statistical power, further studies with larger and more diverse populations are needed to validate these findings across different patient demographics and surgical procedures.

7. CONCLUSION

It is concluded that low tidal volume ventilation during one-lung ventilation in thoracic surgery patients is associated with improved postoperative respiratory function and a significant reduction in pulmonary complications, including atelectasis, pneumonia, and ARDS. Patients in the low tidal volume group also experienced shorter ICU and hospital stays compared to those in the high tidal volume group, reflecting a faster recovery and fewer postoperative complications. These findings highlight the benefits of adopting a lung-protective ventilation strategy, particularly in high-risk surgical populations, to improve clinical outcomes and optimize recovery.

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