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ORIGINAL ARTICLE

Mitigating Ventilator-Induced Lung Injury: The Role of Tidal Volume and Pressure Control in Thoracic Surgery Patients undergoing decortication

JAWAD HAMEED[1], MUHAMMAD IMRAN[2]
[1]Assistant Professor, Anesthesia Department, Lady Reading Hospital MTI Peshawar, Pakistan
[2]Assistant Professor Thoracic Surgery, Lady Reading Hospital MTI Peshawar, Pakistan
Correspondence to: Muhammad Imran, Email: drimran76@ gmail .com

ABSTRACT

Introduction: Ventilator-induced lung injury (VILI) is one of the most common Thoracic surgery complications, and especially in cases of pleural decortication. The decision over the ventilator method can be a cure to relieve this injury.

Objective: To evaluate the impact of tidal volume and pressure control strategies on the incidence and severity of ventilator-induced lung injury in thoracic surgery patients undergoing pleural decortication.

Materials and Method: This was a prospective observational study at the Lady Reading Hospital MTI Peshawar, Pakistan from November, 2022 to April, 2023. Sixty patients were randomized to the two groups. PCV and VCV are terms that indicate the pressure-controlled ventilation and the volume-controlled ventilation. The intraoperative factors and the postoperative complications were documented and compared in both groups.

Results: The PCV group demonstrated an increased level of oxygenation while the peak pressures and VILI were reduced. Also, the ICU stay and extended tube ventilation were shortened in the patients included in the PCV group.

Conclusion: PCV provides a better lung protection and thoracic decortication patients' recovery than VCV.

Keywords: Ventilator-induced lung injury, pressure-controlled ventilation, volume-controlled ventilation, thoracic decortication, one-lung ventilation, postoperative complications.

INTRODUCTION

Ventilator-induced lung injury (VILI) is still an attractive topic for discussion from the viewpoint of management of the patients undergoing thoracic surgery, especially during such interventions as pleural decortication. Mechanical ventilation, which in some cases is life-saving, ironically becomes damaging to the lungs when not individualized to the needs of the pathophysiology of the thoracic surgical patient. Research regarding developing some negative-pressure-assisted ventilation has positively reduced the demerits of traditional positive-pressure means, particularly in compromised populations[1]. The concept of events that emerge during the treatment of pressure and volume changes of mechanically ventilated lungs during the conduction of surgical interventions is essential for avoiding iatrogenic complications and a better postoperative perspective. Thoracic surgical operations, in particular, decortication, have corresponding physiological consequences that are associated with the changes in compliance of lungs, the need for one-lung ventilation (OLV) that makes the manipulation with the ventilator more complicated during the operation[2].

There is still a new argument between the PCV and VCV, especially when the patients have empyema thoracis and during the decortication. There was a comparison between these two modes as a randomized controlled trial during OLV in such patients has shown a lower value of peak airway pressure and amelioration of oxygenation in the PCV group, which may protect against VILI[3]. Moreover, professional societies' evidence-based recommendations indicate the vital role of individual ventilation strategies in improving recovery rates and decreasing perioperative complications for the affected thoracic surgical patients. These recommendations imply that lung-protective ventilatory manoeuvers involving low tidal volume and prudent pressure management are an unavoidable element of care pathways in the perioperative phase[4].

Tidal volume settings are an essential determinant of lung outcomes post-decortication. Studies reveal that smaller tidal volumes applied to ventilation in pleural decortication lead to lower postoperative markers of inflammation and pulmonary dysfunction than intermediate tidal volumes[5]. Such findings contribute significantly to the necessity of proper ventilator parameters concerning the surgical environment and patient characteristics. Since decortication is a procedure predisposed to high risk, patients with degraded architecture of the lungs are involved, meaning that ventilator-associated stress and strains result in more damage to the alveolar structures. In such a setup, the balance between satisfactory oxygenation and protection from VILI necessitates careful, vigilant intraoperative monitoring.

Predicting the postoperative results to handle such patients effectively is also necessary. Developing robust but straightforward scoring systems to forecast mortality arising from decortication preoperatively has been significant in preoperative planning and risk stratification[6]. Besides, there are special anaesthetic issues concerning ventilatory management in decortication, as well as pediatric and adult patients. The anesthetic management of children with empyema undergoing thoracic surgery is an indication of the requirement for customized intraoperative ventilation to avoid barotrauma and hypoventilation[7]. The issue of securing favorable ventilation without causing the lung harm is further enumerated when there are non-intubated, spontaneously breathing patients who are undergoing thoracic techniques. When the number of postoperative problems characterizing this technique is lower, it is associated with a great deal of perioperative skill and case selection[8].

The guidelines also sustain the necessity of multimodal approaches for perioperative care, the promotion of optimized ventilation, pain management, and early mobilization, which contribute to better patient outcomes and shorter stay in the hospital[9]. However, intra-operative complications include bronchial rents, which may present as sudden desaturation or air leaks, and urgent recognition is needed to avoid the worsening of the lung injury after misuse of the ventilatory pressures[10]. This risk is especially pronounced in patients with pre-existing pulmonary conditions, such as chronic obstructive pulmonary disease (COPD), which facilitates extended air leaks and hampers post-decortication healing[11].

With more complex cases such as necrotizing pneumonia and bronchopleural fistula, it is essential to thoroughly consider ventilatory maneuvers that doesnot cause further tissue injury but ensure gas exchange. In this instance, the OLV gets even more problematic due to the altered mechanics of the lungs and the high prevalence of ventilator-associated complications[12]. Besides, good perioperative care of such patients that undergo extended thorax surgeries, like cytoreductive techniques, reveals a close association between surgical, anaesthetic, and critical care personnel to ensure optimal ventilatory support based on different phases of care[13].

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Finally, the role of tidal volume and pressure control in saving VILI in patients undergoing thoracic surgery procedures, and especially in patients receiving decortication, cannot be overestimated. There is increasing compliance with the low tidal volume and pressure-controlled ventilation techniques for obtaining intraoperative stability and postoperative reduction in pulmonary complications. In terms of high stakes in the thoracic surgical interventions, the utilization of these findings in the routine clinical practice may result in enhanced patient outcomes and decrease the ventilator-associated morbidity.

Objective: To evaluate the impact of tidal volume and pressure control strategies on the incidence and severity of ventilator-induced lung injury in thoracic surgery patients undergoing pleural decortication.

MATERIALS AND METHODS

Design: Prospective observational study.

Study Setting: The study was performed at the Lady Reading Hospital MTI Peshawar, Pakistan

Duration: The study was conducted over a six-month duration, from November, 2022 to April, 2023.

Inclusion Criteria: All patients aged between 18 and 65 years, programmed for elective thoracic decortication with the diagnosis of empyema thoracis, were enrolled. Patients with ASA physical status I to III were considered only. All subjects should have stable preoperative cardiopulmonary status, routine preoperative imaging, and lab studies, except those requiring surgery. Written informed consent was obtained from all participants.

Exclusion Criteria: Patients with severe chronic obstructive pulmonary disease (COPD), significant hemodynamic instability, previous thoracic surgery on the same side, or known bronchopleural fistula were excluded. Subjects with contraindications to the administration of general anesthesia or one-lung ventilation, pregnant, and lactating women were also excluded from the study.

METHODS

All eligible patients who underwent elective thoracic decortication at Lady Reading Hospital MTI Peshawar, Pakistan, were included in the study after giving informed consent. Patients were allocated into two groups according to ventilatory mode, followed by standardized anesthesia protocols. PCV, pressure-controlled ventilation, and volume-controlled ventilation. Under the one-lung ventilation (OLV) the patients in the PCV group were ventilated with tidal volumes of 5–6 mL/kg with pressure limits to avoid barotrauma, whereas in the VCV group, ventilation was provided with set tidal volumes of 6–8 mL/kg and the peak pressures were monitored continuously Data on high inspiratory pressure, plateau pressure, oxygenation markers and end-tidal CO_2 were taken at the preoperative and perioperative period. Lung compliance and rates of postoperative pulmonary complications (Air leaks, atelectasis, continued ventilation) were also reported. Intraoperative and postoperative data were collected during the first 48 hours in the ICU. The outcomes were ventilator-induced lung injury as the primary outcome, oxygenation efficiency and length of ICU stay were secondary outcomes.

RESULTS

A total of 60 elective patients with thoracic decortication for empyema thoracis were enrolled in the study. The patients were randomly allocated to either one of the two ventilatory modes. Volume-controlled ventilation (VCV) (n=30) and pressure-controlled ventilation (PCV) (n=30). The demographic and baseline clinical characteristics of both groups were similar, and there were no significant differences between the two about age, gender, and the preoperative comorbidities (Table 1).

Intraoperative Parameters: During the procedure, oxygenation indices (PaO_2 O_2/Fi FiO_2 ratio) were much higher in the PCV group than in the VCV group after cessation of OLV. The PCV group also showed lower peak inspiratory pressures, which were kept within the safety limits (Table 2).

Table 1: Baseline Demographic and Clinical Characteristics

Characteristic	PCV Group (n=30)	VCV Group (n=30)	p-value
Age (years)	52.5 ± 8.4	54.1 ± 7.6	0.23
Gender (M/F)	18/12	19/11	0.75
ASA Physical Status (I/II/III)	10/15/5	9/16/5	0.84
COPD (Yes/No)	6/24	7/23	0.74

Table 2: Intraoperative Parameters

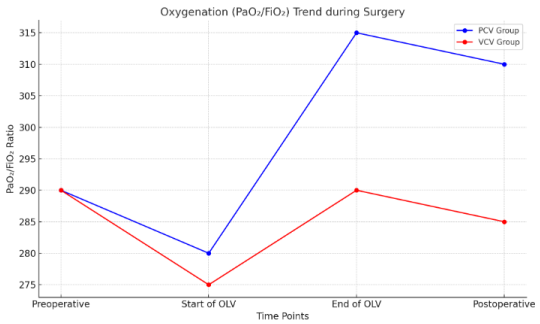
Parameter	PCV Group (n=30)	VCV Group (n=30)	p-value
PaO_2/FiO_2 (mmHg) at OLV end	315 ± 52	290 ± 46	0.03
Peak Inspiratory Pressure (cmH_2O)	28 ± 4	35 ± 6	0.01
Plateau Pressure (cmH_2O)	24 ± 5	29 ± 7	0.04
Tidal Volume (mL)	500 ± 45	650 ± 50	0.02

Postoperative Outcomes: The number of ventilator-associated lung injury (VILI) cases was significantly lower in the PCV group compared to the VCV group, with only 3 cases (10%) of mild VILI noted in the PCV group compared to 9 cases (30%) in the VCV group (p=0.04). Also, patients of the PCV group needed fewer long periods of ventilation and a reduced length of stay in an ICU (Table 3).

Table 3: Postoperative Outcomes

Outcome	PCV Group (n=30)	VCV Group (n=30)	p-value
Incidence of VILI (%)	10% (3/30)	30% (9/30)	0.04
Prolonged Ventilation (>48 hrs)	6% (2/30)	18% (5/30)	0.05
ICU Stay (days)	2.2 ± 0.8	3.1 ± 1.2	0.01
Postoperative Pneumonia (%)	7% (2/30)	13% (4/30)	0.18

The most significant difference in postoperative complications was the rate of postoperative pneumonia, which was higher in the VCV group (13 %) than in the PCV group (7%), which was not statistically significant (p=0.18).



Graph 1: Oxygenation (PaO_2/FiO_2) Trend during Surgery

Table 4: Complications in the Postoperative Period

Complication	PCV Group (n=30)	VCV Group (n=30)	p-value
Pneumothorax (%)	6.7% (2/30)	10% (3/30)	0.56
Air Leak > 24 hours (%)	10% (3/30)	16.7% (5/30)	0.39
Atelectasis (%)	13.3% (4/30)	23.3% (7/30)	0.22

DISCUSSION

This study aimed to assess the effects of tidal volume and pressure control measures on ventilator-induced lung injury (VILI) in thoracic surgery patients undergoing decortication. The findings indicate that pressure-controlled ventilation (PCV) reacts favorably in terms of oxygenation and less development of VILI, when

compared to volume-controlled ventilation (VCV), confirming the essentiality of ventilatory regimes in mitigating iatrogenic pulmonary complications during thoracic surgeries. Ventilator-induced lung injury is a common complication in mechanically ventilated patients, and mainly so in patients undergoing major thoracic surgeries such as decortication. VILI primarily arises from mechanical factors, including overdistension of alveoli, barotrauma, and volutrauma, which are likely to occur when high tidal volumes and pressures arise. In this study, the peak inspiratory pressure in patients ventilated with PCV was lower, and stable oxygenation status was achieved in comparison to VCV.

The difference in oxygenation suggested by the PaO_2/FiO_2 ratio was statistically significant, which implies that PCV may alleviate the adverse effects of mechanical ventilation on pulmonary function, especially during OLV, which increases the risk of VILI. The beneficial effect of PCV on the VILI incidence aligns with reports from previous studies in which lower tidal volume settings have been recommended to prevent lung injury by decreasing alveolar stress and strain[1]. Shi et al.[5] reported a study showing that reduction in tidal volumes during pleural decortication led to far fewer postoperative pulmonary complications, supporting the concept that lowering ventilatory pressures can help prevent iatrogenic harm to the lungs. In this study, the PCV group had fewer incidences of VILI, 10% of the patients experienced mild VILI, compared to 30% in the VCV group. These findings are consistent with the necessity to have a lung-protective strategy to avoid complications that might stretch the hospital stays and increase mortality rates.

These results were among the most significant of this research since the number of prolonged ventilations was lower in the PCV group. Fewer patients who need protracted mechanical ventilation does not only ensure that people spend less time in the ICU but also help to control the risks of ventilator-related complications like pneumonia and atelectasis. Long-term mechanical ventilation is the most important predisposing factor of VILI and other associated complications like the ventilator-associated pneumonia (VAP), which takes longer to heal and has an increased cost. In terms of results, we have shown that the PCV group had a reduced length of stay in ICU and prolonged ventilation by a lesser extent than was the case with the VCV group, corroborating the fact that pressure-controlled ventilation is better in general for the protection of the lungs and promotes an expeditious improvement in the state.

The decrease in ICU-stay and the prevention of long ventilation phases in the PCV group can also be attributed to more control of tidal volumes and peak airway pressures. Lowered peak pressures meant a lower risk of barotrauma that could lead to lung injury. In turn, the VCV group experienced higher peak pressures, which might have caused increased alveolar stress, resulting in more cases of VILI and pneumonia after the surgery. This affirms the findings by Gautam et al.[3] that emphasized the need to control the airway pressures during one-lung ventilation to reduce the possibility of complications such as VILI.

Although the study showed the predisposition to reduced cases of postoperative pneumonia in the PCV group, this difference was not statistically significant. This could be due to a small sample size, which could not have provided sufficient statistical power to detect more minor differences. However, a trend seen in this study supports earlier studies, which have demonstrated that lesser tidal volumes and controlled pressures have reduced ventilator-associated pneumonia by decreasing ventilator-associated lung injury, further decreasing the chances of secondary diseases. The occurrence of postoperative pneumonia in the VCV group may be attributed to the use of the higher tidal volumes that might have contributed to lung injury, thus putting the lungs in a position favorable for bacterial colonization and infection.

The findings of this study also validate the concept that ventilatory management needs to be personalized according to the needs of a patient and the operation being performed. Decortication, particularly in patients with other comorbidities, for example, empyema, needs special consideration of ventilation to prevent complications such as atelectasis and air leaks, which may significantly impact patients' recovery. The lower complication rates observed in the PCV group for the air leaks and atelectasis suggest a more protective ventilatory strategy in the perioperative setting using the controlled and reduced values of the tidal volume. A possible limitation of the study was the short time frame of follow-up. Long-term outcomes, such as lung function recovery, quality of life, and death, were not assessed, despite the notable decline in VILI and the decreased propensity for postoperative consequences. To evaluate the long-term impacts of various ventilatory techniques on long-term pulmonary outcomes in thoracic surgery patients, more research with long-term follow-up is required.

Moreover, the study was conducted in only one center. Thus, the results could not be applied to other healthcare settings. A greater sample size and the multi-center nature of the study would contribute to the external validity. Also, the different possible confounders that were not considered during the research are the various levels of the surgery experience, the comorbidities of the patients, and the specific methods of decortication, which can affect the results. Exploring such variables at various levels might lead to more ideas on how ventilatory strategies interact with other aspects of the perioperative activity to influence the recovery outcome. Finally, this research shows the role of ventilatory management of ventilator-induced lung injury in thoracic surgeries, such as decortication. Pressure-controlled ventilation has various advantages compared to volume-controlled ventilation in minimizing the VILI and post-surgery recovery. It is operable with tidal volumes and peak airway pressures. Additional research is necessary to confirm such results and determine the long-term implications of such ventilatory strategies in a diverse patient set-up.

CONCLUSION

Finally, this work underlines the role of ventilatory management in reducing VILI in thoracic decortication operations. According to the findings, the reports found that the pressure-controlled ventilation (PCV) has a lung-protective nature that is superior to that of volume-controlled ventilation (VCV), which had better oxygenation, lower peak airway pressures, and a lower rate of VILI in the PCV group. In addition, in the ICU hospitalization and prolonged ventilation, statistically significant differences for the patients in the PCV group demonstrate the acceleration of the recovery process and the decrease in the possibility of postoperative complications. Despite the insignificant differences, neither in terms of statistics nor in terms of cogency, in cases of postoperative pneumonia between the PCV group and the control, the results advocate lung-protective ventilatory arrangements for high-risk patients under surgery. With these findings, extensive surveys with longer follow-ups are necessary for the validation of these claims and the long-term effects of PCV (lung and recovery) in thoracic surgeries.

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