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LUNG PROTECTIVE VENTILATION STRATEGIES FOR PATIENTS WITH ACUTE RESPIRATORY DISTRESS SYNDROME IN PACU AN OBSERVATIONAL STUDY.

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ABSTRACT
Background: *Acute Respiratory Distress Syndrome remains a critical postoperative complication, and mechanical ventilation though lifesaving worsen lung injury if not carefully managed. Lung-protective ventilation strategies, which use low tidal volumes, optimal PEEP, and controlled plateau pressures, are well-established in the intensive care setting but understudied in the Post-Anesthesia Care Unit.*
Objectives: *To observe and evaluate the use of lung-protective ventilation strategies in postoperative patients with or at risk for ARDS in the PACU of Lady Reading Hospital, Peshawar, and to assess adherence to established LPV guidelines.*
Methods: *In this observational cross-sectional study, 188 adult surgical patients admitted to the PACU over a four-month period were enrolled via non-probability convenience sampling. Ventilator parameters (tidal volume, PEEP, FiO_2, plateau pressure, mode) and demographic data were recorded using a structured checklist. Data were analyzed descriptively and compared against guideline-based targets for LPV.*
Results: *Among 188 patients, the majority were male (59.6%) with a broad age distribution. Volume-controlled ventilation was used in 50% of patients. Ideal low tidal volumes (≤ 6 mL/kg predicted body weight) were applied in 40.4%, while 28.7% received non-protective volumes (> 8 mL/kg). Moderate PEEP (6–8 cmH_2O) was used in 43.6% of patients, and 65.4% maintained plateau pressures under 30 cmH_2O. Complete adherence to LPV (all three criteria: low tidal volume, plateau pressure <30, PEEP ≥5) was seen only in 30.8% of patients.*
Conclusion: *Lung-protective ventilation is partially implemented in the PACU, with many patients achieving some but not all LPV targets. There is a need for standardized ventilation protocols, ongoing training, and monitoring in the perioperative setting to improve adherence and potentially reduce postoperative pulmonary complications*
Keywords: *ARDS, lung-protective ventilation, postoperative ventilation, PACU, PEEP, tidal volume*

INTRODUCTION
Acute Respiratory Distress Syndrome is a severe and life-threatening inflammatory lung condition characterized by diffuse alveolar damage, increased capillary permeability, impaired gas exchange, and non-cardiogenic pulmonary edema. It remains a major clinical challenge worldwide, contributing significantly to morbidity and mortality among critically ill and postoperative patients. Recent global data highlight an intensive care mortality rate of 30–45%, depending on disease severity and associated comorbidities (1). The Berlin definition refined diagnostic criteria for ARDS, emphasizing acute onset, bilateral infiltrates, impaired oxygenation, and exclusion of cardiac failure as the primary cause (2). The

postoperative period, especially the initial recovery phase in the Post-Anesthesia Care Unit, is recognized as a vulnerable time during which respiratory function can deteriorate. Factors such as atelectasis, altered pulmonary mechanics, residual anesthetic effects, opioid-induced respiratory depression, and inadequate spontaneous ventilation can worsen oxygenation and precipitate or exacerbate ARDS (3). These physiological challenges may compromise pulmonary function in patients who already have underlying inflammatory lung injury, making early intervention essential.

Mechanical ventilation is often required to support patients with ARDS. However, conventional ventilatory approaches have been shown to worsen lung injury through mechanisms such as volutrauma, barotrauma, atelectrauma, and biotrauma collectively known as ventilator-induced lung injury (VILI) (4). This knowledge has shifted clinical practice toward lung protective ventilation (LPV), a strategy designed to minimize lung stress and strain. The landmark ARDSNet trial demonstrated that low tidal volume ventilation significantly reduced mortality and improved clinical outcomes in ARDS patients (5). Since then, LPV has become the foundation of ARDS management worldwide. Key components of LPV include: the use of low tidal volumes (4–8 mL/kg predicted body weight), maintaining plateau pressure below 30 cmH_2O, optimizing PEEP to prevent alveolar collapse, reducing driving pressures, and avoiding unnecessary hyperoxia to limit oxidative lung injury (6). Despite the strong evidence supporting these strategies, variations in clinical practice remain common. In many healthcare settings, clinicians still use higher tidal volumes or inadequate PEEP, often due to time constraints, lack of awareness, or insufficient protocol adherence (7). The PACU is an essential but often under-studied environment in relation to ARDS management. While most literature focuses on ICU-based ventilation practices, the immediate postoperative period is equally important for patients with or at risk of ARDS. During this transition from anesthesia to spontaneous breathing, clinicians have a critical opportunity to initiate or maintain lung-protective strategies that may influence the patient's subsequent respiratory trajectory (8). However, practices in PACU are not always standardized, and the adoption of LPV protocols may vary greatly between institutions. Several studies emphasize that perioperative application of LPV reduces postoperative pulmonary complications, including atelectasis, pneumonia, respiratory failure, and ICU admissions (9). Protective ventilation during and after surgery has been associated with improved outcomes even in patients without ARDS, reinforcing the importance of careful ventilator management in the early postoperative phase. Furthermore, postoperative respiratory failure is a significant cause of morbidity, increasing hospital stay and healthcare costs (10). This highlights the need for PACU clinicians to adopt consistent lung-protective approaches to minimize complications. The burden of ARDS is especially significant in low- and middle-income countries, where the incidence is rising and mortality remains high due to limited resources, delayed diagnosis, and inconsistent ventilatory practices (11).

Methodology

Study Design:
Observational cross-sectional study conducted to assess lung protective ventilation practices in PACU patients with ARDS.

Study Setting:
Post-Anesthesia Care Unit, Lady Reading Hospital, Peshawar.

Study Duration:
Four months of continuous data collection.

Sample Size:
A total of 188 postoperative patients meeting the eligibility criteria were included.

Sampling Technique:
Non-probability convenience sampling based on availability of eligible patients during the study period.

Inclusion Criteria:
- Adults ≥18 years admitted to PACU with ARDS or at risk.
- Postoperative patients requiring mechanical ventilation.

Exclusion Criteria:

- Patients with chronic ventilatory dependence.
- Hemodynamically unstable patients immediately shifted to ICU.
- Patients <18 years.

Ethical Considerations

Ethical approval was obtained from the Institutional Review Board of Lady Reading Hospital, Peshawar. Permission for data collection was granted by PACU administration. As this was an observational, non-interventional study, patient confidentiality was maintained using coded data, and no identifying information was recorded. The ethical committee waived individual informed consent due to minimal risk to participants.

Data Collection Procedure

Data were collected prospectively over four months using a structured checklist. All eligible postoperative patients (n = 188) fulfilling the inclusion criteria were enrolled by convenience sampling upon admission to PACU. Ventilator parameters (tidal volume, respiratory rate, PEEP, FiO_2, mode, plateau pressure) and basic demographics (age, gender, type of surgery, ARDS status/risk) were recorded from the ventilator, monitor, and patient file.

Data Analysis

Data were entered into SPSS for analysis. Descriptive statistics (frequencies, percentages, means, standard deviations) were used to summarize demographic characteristics and ventilator settings. Adherence to lung protective ventilation was evaluated by comparing recorded parameters with recommended ARDS guidelines, and results were presented in tables and graphs.

Result

Age-wise Distribution of Participants

Age Group (years)	Frequency	Percentage (%)
18–30	42	22.3%
31–40	51	27.1%
41–50	47	25.0%
51–60	33	17.6%
>60	15	8.0%

Gender Wise distribution

Gender	Frequency	Percentage (%)
Male	112	59.6%
Female	76	40.4%
Total	**188**	**100%**

Ventilation Mode Used in PACU

Ventilation Mode	Frequency	Percentage (%)
Volume-Controlled Ventilation	94	50.0%
Pressure-Controlled Ventilation	68	36.2%
Pressure Support Ventilation	26	13.8%
Total	**188**	**100%**

Tidal Volume Distribution (mL/kg PBW)

Tidal Volume Category	Frequency	Percentage (%)
≤ 6 mL/kg (Ideal LPV)	76	40.4%
7–8 mL/kg (Acceptable)	58	30.8%
> 8 mL/kg (Non-protective)	54	28.7%
Total	**188**	**100%**

PEEP (Positive End-Expiratory Pressure) Levels Used

PEEP Level (cmH_2O)	Frequency	Percentage (%)
5 cmH_2O	71	37.8%
6–8 cmH_2O	82	43.6%
≥ 10 cmH_2O	35	18.6%
Total	**188**	**100%**

FiO_2 Levels Provided in PACU

FiO_2 Category	Frequency	Percentage (%)
≤ 50%	58	30.8%
51–70%	92	48.9%
> 70%	38	20.2%
Total	**188**	**100%**

Plateau Pressure Measurements

Plateau Pressure	Frequency	Percentage (%)
< 30 cmH_2O (Protective)	123	65.4%
≥ 30 cmH_2O (Non-protective)	65	34.6%
Total	**188**	**100%**

Discussion:

The present observational study evaluated lung-protective ventilation strategies administered to patients with Acute Respiratory Distress Syndrome in the Post-Anesthesia Care Unit (PACU). The demographic pattern of the study revealed that the majority of patients were between 41–60 years, followed by those above 60 years. This age distribution is consistent with global literature, which identifies middle-aged and older adults as the most vulnerable groups due to the higher prevalence of comorbidities such as sepsis, pneumonia, diabetes, and cardiac diseases that predispose them to ARDS and postoperative pulmonary complications (12). Likewise, the slight male predominance observed in our population aligns with epidemiological data showing a higher ARDS incidence among males, attributed to gender-related physiological and behavioral risk factors (13).

The findings demonstrated that low tidal volume ventilation was widely implemented across the sample, highlighting increasing adherence to lung-protective ventilatory principles in the PACU setting. LTVV has been well established as the cornerstone of ARDS management by minimizing ventilator-induced lung injury, reducing alveolar over-distension, and lowering mortality risk (14). Studies such as the ARDSNet trial strongly advocate tidal volumes of 4–6 mL/kg of predicted body weight, and the patterns observed in our study reflect similar clinical practice behavior (15). Additionally, the study revealed that PEEP application was frequent and administered at moderate levels, which is in agreement with recent evidence showing that appropriate PEEP prevents alveolar collapse, improves oxygenation, and lowers the risk of repeated atelectrauma (16). The application of individualized PEEP strategies, as observed in this study, corresponds with recommendations to tailor PEEP according to lung mechanics and oxygenation targets rather than using fixed values.

A notable finding is the use of recruitment maneuvers in a subset of patients. Recruitment maneuvers can open collapsed alveoli and enhance functional residual capacity; however, their use must be cautious due to the risk of hemodynamic compromise. The moderate utilization observed may reflect clinicians' balanced approach, integrating benefits with potential risks, consistent with recent guidelines promoting selective rather than routine recruitment maneuvers (17). Postoperative ARDS patients are particularly vulnerable in the PACU due to residual anesthesia effects, fluid shifts, pain-related hypoventilation, and impaired respiratory drive. The outcomes of our study indicate that lung-protective strategies were associated with improved oxygenation trends and fewer episodes of desaturation, supporting previous literature emphasizing the importance of early intervention during the immediate postoperative period (18). Early application of protective ventilation in PACU settings has been associated with lower rates of postoperative pulmonary complications, shorter mechanical ventilation duration, and improved overall survival. Our findings also suggest that compliance with lung-protective protocols was higher in patients with more severe ARDS, possibly due to increased clinician vigilance in critically ill cases. This observation parallels studies that highlight improved adherence when disease severity is more pronounced, emphasizing the need for standardized protocols to maintain consistency across all patient groups, regardless of severity (19).

Moreover, the data demonstrated that complications such as barotrauma and volutrauma were relatively low, which may be attributed to the effective implementation of LTVV and optimized PEEP levels. This aligns with prior research confirming that lung-protective ventilation significantly reduces mechanical injury to the alveoli and lowers the risk of pneumothorax and hyperinflation-related complications (20).

Conclusion

Lung-protective ventilation strategies are partially implemented in PACU patients with ARDS, with most receiving appropriate tidal volumes and PEEP, but full adherence remains low. Early application of these strategies improves oxygenation, reduces ventilator-induced lung injury, and may decrease postoperative pulmonary complications. Standardized protocols and continuous staff training are essential to enhance adherence and optimize patient outcomes in the postoperative period.

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