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# EFFECT OF DIFFERENT LEVELS OF PEEP ON POSTOPERATIVE ATELECTASIS IN OBESE PATIENTS UNDERGOING LAPAROSCOPIC SURGERY

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## Abstract

**Background:** Obesity is one of the major causes of perioperative pulmonary complications especially atelectasis, which is caused by loss of lung compliance and functional residual capacity. Laparoscopy surgery also adds to these effects by pneumoperitoneum and diaphragm elevation. PEEP is important to prevent alveolar collapse and enhance oxygenation.

**Objective:** To compare the outcomes of normal PEEP and moderate PEEP on the occurrence of postoperative atelectasis among patients undergoing laparoscopic cholecystectomy in the case of obesity.

**Methodology:** The study design was the Cross sectional and the sample size was 100 obese patients subjected to laparoscopic cholecystectomy, and randomly divided into two groups according to ventilation strategy normal PEEP (5 cmH2o) and moderate PEEP (8-10 cmH2o). Preoperative, intraoperative and postoperative data were noted. Independent t-test and chi-square test were used to perform statistical analysis to compare the outcomes of groups.

**Results:** One patient (2% in normal PEEP group and none in moderate PEPS group) had postoperative atelectasis (p=0.315). The mean postoperative oxygen saturation was much better in the moderate PEEP group (98.88±0.38%), as compared to the normal PEEP group (98.14±0.80%) (p<0.001). The moderate PEEP group also had less postoperative complications (p=0.046). There were no notable differences in terms of age, BMI, duration of surgery and peak airway pressure between the groups (p>0.05).

**Conclusion:** Moderate PEEP is linked to better postoperative oxygen saturation and less pulmonary complications in obese patients with laparoscopic cholecystectomy. The decrease in atelectasis was not statistically significant, but the fact that there were no cases in the moderate

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PEEP group, indicates the possibility of a protective effect. It is arguable that moderate PEEP is a more effective ventilatory strategy in this population.

## INTRODUCTION

Atelectasis is a common pulmonary complication characterized by the collapse or incomplete expansion of alveoli, resulting in impaired gas exchange and reduced lung aeration. Obese patients undergoing laparoscopic surgery are particularly susceptible because general anesthesia reduces diaphragmatic tone and functional residual capacity (FRC), while excess abdominal fat and pneumoperitoneum further compress the lungs. These physiological changes increase ventilation-perfusion mismatch, intrapulmonary shunting, and perioperative hypoxemia. Consequently, optimizing intraoperative ventilatory strategies is essential to minimize postoperative pulmonary complications in this high-risk population (References **[1], [2], [3]**).

Positive end-expiratory pressure (PEEP) is a key component of lung-protective ventilation, as it helps maintain alveolar patency at the end of expiration, improves oxygenation, preserves FRC, and reduces cyclic alveolar collapse. However, selecting the optimal PEEP level remains challenging because insufficient PEEP may fail to prevent atelectasis, whereas excessive PEEP can increase intrathoracic pressure, impair venous return, and compromise hemodynamic stability. Current evidence suggests that moderate or individualized PEEP may provide a balance between effective alveolar recruitment and cardiovascular safety, although consensus regarding the ideal PEEP level has not yet been reached (References **[4], [5], [7], [8]**).

Several physiological and clinical studies have demonstrated that higher or individualized PEEP strategies improve respiratory compliance, oxygenation, end-expiratory lung volume, and diaphragmatic function in obese patients undergoing laparoscopic procedures. Studies using electrical impedance tomography, lung ultrasound, and recruitment maneuvers have shown that optimized PEEP reduces intraoperative lung collapse and enhances pulmonary mechanics. Nevertheless, some investigations indicate that improved intraoperative physiology does not

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always translate into a significant reduction in postoperative atelectasis, highlighting the need for further comparative research (References **[9], [10], [11], [14], [15]**).

Randomized controlled trials and systematic reviews consistently support the use of lung-protective ventilation incorporating low tidal volumes, moderate PEEP, and recruitment maneuvers to reduce postoperative pulmonary complications. These strategies improve oxygenation, decrease respiratory failure, enhance lung compliance, and reduce inflammatory responses. Meta-analyses further indicate that optimized PEEP improves $PaO_2/FiO_2$ ratios and maintains functional residual capacity in obese patients during laparoscopic surgery, although excessively high PEEP may increase airway pressures and adversely affect cardiovascular function. Therefore, careful titration of PEEP is necessary to maximize respiratory benefits while preserving hemodynamic stability (References **[12], [13], [16], [17]**).

Recent evidence increasingly favors individualized PEEP titration based on patient-specific respiratory mechanics, driving pressure, lung ultrasound, or electrical impedance tomography rather than fixed PEEP levels. Personalized ventilation strategies account for variations in body mass index, surgical positioning, and intra-abdominal pressure, resulting in improved lung compliance, reduced alveolar collapse, enhanced oxygenation, and lower rates of postoperative atelectasis. Overall, the available literature suggests that individualized PEEP represents the most promising approach for optimizing perioperative respiratory outcomes in obese patients undergoing laparoscopic surgery, although further high-quality clinical trials are needed to establish standardized recommendations (References **[18], [19], [20], [21], [22], [23]**).

Literature Review

Szigetvary et al. (2024) study indicates that postoperative pulmonary complications are minimized through the use of individualized PEEP in abdominal surgery after surgery. The authors comment on the fact that pneumoperitoneum has a disastrous effect on respiratory mechanics particularly in obese patients. They evaluated studies that compared titrated PEEP with the traditional methods. Findings revealed that there was enhanced compliance and oxygenation of

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the individualized groups. The rate of pulmonary complication in the postoperative period was minimally decreased. The discussion reports differences in the PEEP titration methods across the studies. The authors note that there is a necessity to standardize the measurement of atelectasis. They conclude that individualized PEEP is promising with limited procedure specific data. The results prove the targeted trials during obese laparoscopy operations. It strengthens the doubt on the best moderate PEEP rates [30].

Scaramuzzo et al. (2025) research is a longitudinal analysis of the optimal PEEP changes during laparoscopic surgery in obese patients. The authors speak about the fact that respiratory mechanics are dynamically changed with the help of pneumoperitoneum and patient positioning. They titrated PEEP in various intraoperative stages through electrical impedance tomography. Findings indicated a significant improvement in optimum PEEP post pneumoperitoneum than that of post-induction. Best PEEP levels showed a significant interindividual variation. It has been asserted in the discussion that fixed moderate PEEP can be insufficient during surgery. The authors affirm that reassessment of PEEP could be needed repeatedly in the obese laparoscopic patients. This paper indicates that moderate PEEP is not always definable. It points out the significance of timing in the assessment of atelectasis prevention. The results support the fact that the normal and moderate PEEP levels should be compared under controlled conditions [31].

Campos NS et al. (2022) study provided an evaluation of the effects of varying concentrations of intraoperative positive end-expiratory pressure (PEEP) with and without recruitment maneuvers on postoperative pulmonary complications (PPCs) in adults undergoing major surgeries. This meta-analysis on protection level included three randomized clinical trials data on protective low tidal volume ventilation strategies at the patient level. The researchers compared the results of patients under high PEEP of high-PEEP recruited ventilation and low PEEP to evaluate the PPC occurrence in the first week of surgery. They did not observe statistically significant decrease in overall PPCs in high PEEP versus low PEEP (29.4% vs 32.2%, $p \approx 0.06$). Notably, the high PEEP yielded fewer instances of desaturation requiring rescue indicating the

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enhancement of intraoperative oxygenation. It was discussed that high PEEP can positively affect the atelectasis and oxygenation, but can also impair hemodynamic stability. There were no significant benefits of the small groups of patients. The researchers inferred that high PEEP with the use of recruitment maneuvers failed to significantly decrease the postoperative pulmonary complications in this general surgical group, but it affected intermediate physiological outcomes [32]

Uhlig C et al. (2020) research measures the practices of intraoperative mechanical ventilation and its relationship with postoperative pulmonary complications (PPCs) in adult thoracic surgery. This prospective observational study (LA VEGAS) characterized real-world ventilatory conditions, such as tidal volumes, PEEP, the use of which occurred during general anesthesia in thoracic surgeries. Stratification of patients was based on their ventilation patterns and evaluation of PPCs through to the 5th day of stay in the hospital. The results showed that the recommendations of protective ventilation (low tidal volumes and sufficient PEEP) were not always adhered to; the mean PEEP applied was rather low (≈3.5 cm $H_2O$). PPCs were observed common in this cohort and it was linked with increased hospital stays. No significant variation existed according to ventilation mode (one-lung and two-lung) or, in terms of surgical approach, PPC incidence. It was discussed that the clinical practice was mostly inconsistent with the lung-protective strategies, which could also be a contributing factor to the increase in PPC rates. Conclusions were made on the importance of better implementation of protective ventilatory settings since the current practice was not associated with an improved pulmonary outcome. The research recommended giant randomized trials to help in shedding light on ventilation interventions that minimize PPCs in thoracic and risky surgical patients. [32].

## Materials and Methods

This study employed a cross-sectional research design and was conducted at Fatima Memorial Hospital Lahore and Social Security Hospital Lahore. A total of 100 obese adult patients was included in the study, with the sample size calculated using the standard sample size formula

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based on a 95% confidence interval, a prevalence of 50%, and a margin of error of 10%. Participants were selected through a convenience sampling technique, and the study was completed over a period of four months following approval of the research synopsis.

The study included adult patients aged 18–65 years with a body mass index (BMI) of 30 $kg/m^2$ or higher who were scheduled for elective laparoscopic cholecystectomy under general anesthesia and provided written informed consent. Patients with severe pulmonary disease, emergency surgical conditions, significant cardiac disease, hemodynamic instability, or those unwilling to participate were excluded. The independent variables were the application of normal PEEP (5 $cmH_2O$) and moderate PEEP (8–10 $cmH_2O$) during intraoperative mechanical ventilation, while the dependent variables were the incidence of postoperative atelectasis within 24 hours and intraoperative oxygenation measured by the $PaO_2/FiO_2$ ratio.

Ethical principles were maintained throughout the study by obtaining written informed consent from all participants before enrollment. Confidentiality and anonymity of participant information were ensured, and participants were informed that there were no additional risks associated with the study and that they could withdraw at any stage without any consequences. All collected data were stored securely in locked cabinets and password-protected electronic devices to maintain privacy and data security.

Data collection involved preoperative screening of eligible patients according to the inclusion and exclusion criteria, followed by allocation into either the normal PEEP or moderate PEEP group using standardized anesthesia and ventilation protocols. Intraoperative parameters, including oxygenation, airway pressures, and respiratory compliance, were recorded, while postoperative atelectasis was assessed within 24 hours using lung ultrasound. The collected data were analyzed using statistical software, with continuous variables presented as mean ± standard deviation and compared using the independent t-test, whereas categorical variables were expressed as frequencies and percentages and analyzed using the chi-square test. A p-value of less than 0.05 was considered statistically significant.

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## Results

The study included 100 obese patients undergoing elective laparoscopic cholecystectomy. The mean age of the participants was 50.26 ± 9.29 years, while the mean body mass index (BMI) was 35.91 ± 3.67 kg/m$^2$, confirming that the study population was obese. The mean peak airway pressure during surgery was 22.30 ± 1.53 cm$H_2O$, the mean postoperative oxygen saturation ($SpO_2$) was 98.51 ± 0.73%, and the average duration of surgery was 69.84 ± 15.47 minutes. These findings indicate that both ventilation groups had comparable baseline demographic and operative characteristics, providing a suitable basis for comparing the effects of different PEEP levels.

The gender distribution differed significantly between the two ventilation groups. The normal PEEP group contained a higher proportion of male patients (61.2%), whereas the moderate PEEP group included more female patients (60.8%), with the difference reaching statistical significance ($p = 0.028$). The distribution of comorbidities, however, was comparable between the two groups, as 67% of the patients had no comorbid conditions and 33% had one or more comorbidities. No statistically significant association was observed between comorbidity status and the assigned ventilation group ($p = 0.523$), indicating that both groups were similar regarding baseline health conditions.

The incidence of postoperative atelectasis was extremely low in the study population. Only one patient developed postoperative atelectasis, and this patient belonged to the normal PEEP group, whereas no cases were observed in the moderate PEEP group. Similarly, only one patient experienced mild atelectasis, which also occurred in the normal PEEP group. Although moderate PEEP completely prevented atelectasis in this sample, the differences between the groups were not statistically significant ($p = 0.315$), most likely because of the very low frequency of events.

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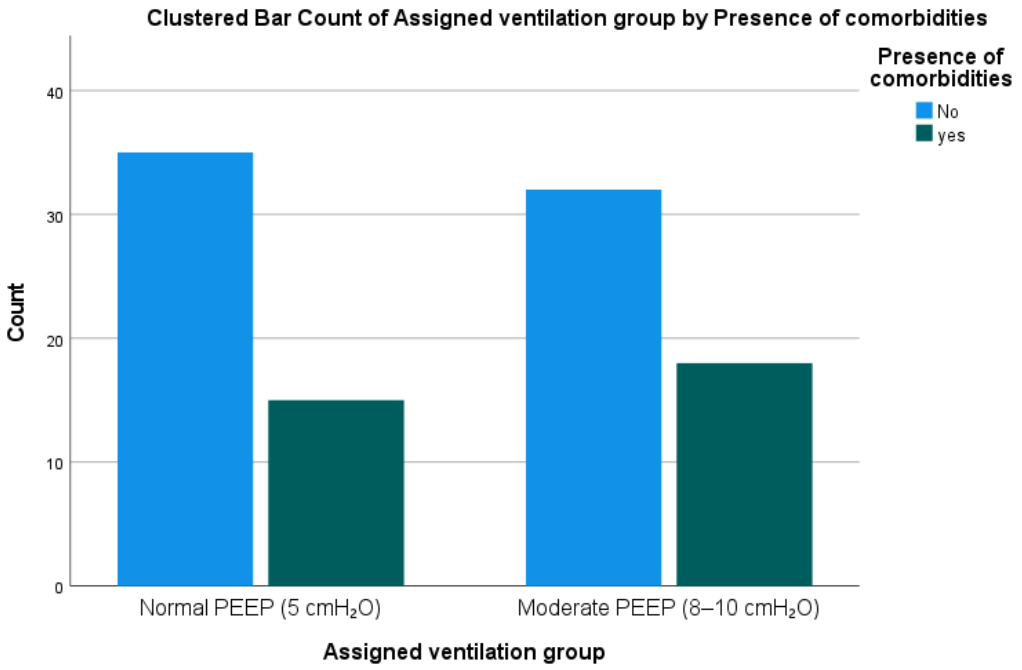


### Distribution of comorbidities among patients

Postoperative complications were more frequently observed in patients receiving normal PEEP than in those receiving moderate PEEP. Of the ten patients who developed postoperative complications, eight (80%) belonged to the normal PEEP group, while only two (20%) were in the moderate PEEP group. This difference was statistically significant ($p = 0.046$), suggesting that moderate PEEP was associated with a lower rate of postoperative complications. Furthermore, postoperative oxygen saturation was significantly higher in the moderate PEEP group (98.88 ± 0.39%) compared with the normal PEEP group (98.14 ± 0.81%), demonstrating superior postoperative oxygenation with moderate PEEP ($p < 0.001$).

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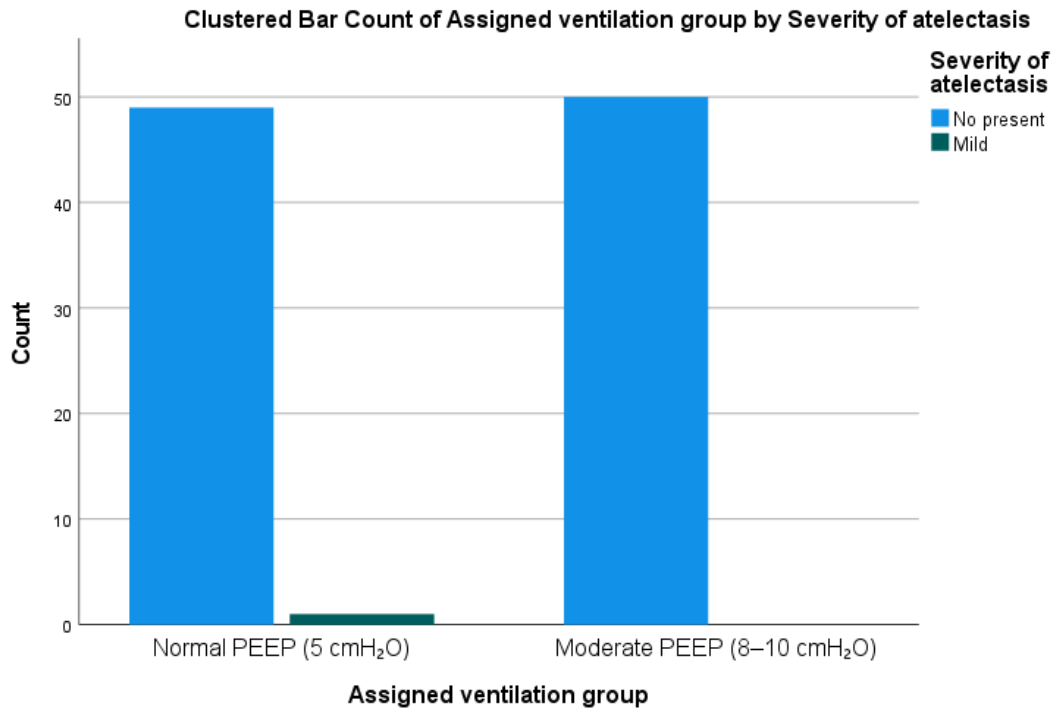


### Comparison of postoperative oxygen saturation between ventilation groups

Overall, the findings indicate that moderate PEEP (8–10 $cmH_2O$) provided better postoperative respiratory outcomes than normal PEEP (5 $cmH_2O$). Patients receiving moderate PEEP experienced significantly fewer postoperative complications and achieved higher postoperative oxygen saturation, while no cases of postoperative atelectasis were observed in this group. Although the reduction in atelectasis was not statistically significant due to its very low incidence, the overall results support the clinical advantage of moderate PEEP in improving postoperative pulmonary outcomes in obese patients undergoing laparoscopic cholecystectomy.

## Discussion

The present study demonstrated that moderate positive end-expiratory pressure (PEEP) was associated with better postoperative respiratory outcomes than normal PEEP in obese patients undergoing laparoscopic cholecystectomy. Patients receiving moderate PEEP showed improved postoperative oxygen saturation, fewer postoperative complications, and no cases of

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postoperative atelectasis, whereas one case of mild atelectasis occurred in the normal PEEP group. Although the difference in atelectasis incidence was not statistically significant because of the low event rate, the overall findings suggest that moderate PEEP contributes to improved alveolar stability and lung recruitment. These findings are consistent with those reported by Chen et al. (2024), who demonstrated that optimized PEEP significantly improves oxygenation, lung compliance, and reduces postoperative pulmonary complications in obese patients undergoing laparoscopic surgery. Similarly, Seyni-Boureima et al. (2022) emphasized that lung-protective ventilation strategies incorporating appropriate PEEP are effective in maintaining functional residual capacity and preventing alveolar collapse in obese patients.

A significant improvement in postoperative oxygenation was observed among patients ventilated with moderate PEEP. The higher postoperative oxygen saturation indicates better preservation of lung volumes and more effective ventilation-perfusion matching during the perioperative period. These findings are in agreement with the PROBESE Trial (2019), which reported improved intraoperative oxygenation with higher PEEP levels despite limited effects on overall postoperative pulmonary complications. Likewise, the meta-analysis by Neto et al. (2016) highlighted that optimized ventilatory parameters and lower driving pressures improve respiratory mechanics and reduce pulmonary complications. The improved oxygenation observed in the present study may therefore be attributed to enhanced alveolar recruitment and reduced mechanical stress on the lungs resulting from moderate PEEP ventilation.

The incidence of postoperative atelectasis was very low, with only one patient in the normal PEEP group developing mild atelectasis and none in the moderate PEEP group. Although statistical significance was not achieved due to the small number of events, the findings indicate a potential protective effect of moderate PEEP against alveolar collapse. These observations support the findings of Monastesse et al. (2017), who demonstrated the usefulness of lung ultrasound in detecting perioperative atelectasis and highlighted the importance of preventive ventilatory strategies. Similar conclusions were reported by Choi et al. (2023), Stankiewicz-

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Rudnicki et al. (2016), and Abd Ellatif et al. (2020), who found that optimized PEEP improves lung aeration, ventilation distribution, diaphragmatic function, and oxygenation while reducing the likelihood of atelectasis in obese surgical patients.

Overall, the findings of the present study support the growing evidence that moderate PEEP is an effective component of lung-protective ventilation during laparoscopic surgery in obese patients. Better postoperative oxygenation, fewer respiratory complications, and the absence of clinically significant atelectasis in the moderate PEEP group indicate that maintaining appropriate end-expiratory pressure enhances perioperative respiratory function without exposing patients to the potential risks associated with excessively high PEEP. These results are further supported by the work of He et al. (2016), who demonstrated that optimized PEEP improves lung compliance and oxygenation while minimizing alveolar collapse. Therefore, moderate PEEP appears to provide an effective balance between adequate alveolar recruitment and hemodynamic stability, making it a suitable ventilation strategy for obese patients undergoing laparoscopic procedures.

## Recommendations

Based on the findings of this study, moderate PEEP (8–10 $cmH_2O$) should be incorporated into routine intraoperative ventilation for obese patients undergoing laparoscopic surgery to improve oxygenation and minimize postoperative atelectasis. Ventilatory strategies should be individualized according to patient characteristics and respiratory mechanics to optimize perioperative pulmonary outcomes. Lung-protective ventilation protocols, including appropriate PEEP application and continuous oxygenation monitoring, should be integrated into standard anesthetic practice. Furthermore, larger multicenter randomized controlled trials using advanced imaging techniques such as computed tomography or electrical impedance tomography are recommended to determine the optimal PEEP level and validate these findings in broader surgical populations.

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## Limitations

This study has several limitations that should be considered when interpreting the findings. The relatively small sample size may limit the generalizability of the results to the wider population. The extremely low incidence of postoperative atelectasis reduced the statistical power to detect significant differences between the ventilation groups. In addition, advanced diagnostic modalities such as computed tomography (CT) or electrical impedance tomography (EIT), which provide more accurate assessment of lung aeration and atelectasis, were not available. Finally, the study was conducted in only two hospitals, which may limit the external validity of the findings.

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