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Original Research Article

Comparing effects of different levels of positive end-expiratory pressure on aeration score in laparoscopic surgeries using lung ultrasound: A randomised controlled trial

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Abstract

Background and Aims: Laparoscopic surgeries can lead to pulmonary atelectasis due to pneumoperitoneum and Trendelenburg positioning, affecting respiratory function. Positive end-expiratory pressure (PEEP) is used to improve lung aeration, but the optimal PEEP level remains unclear. Lung ultrasound (LUS) provides a non-invasive method to assess lung aeration. This study was aimed to compare different levels of PEEP (0, 5 and 10 cm H_2O) using lung ultrasound scores in patients undergoing laparoscopic surgeries.

Materials and Methods: A randomized controlled trial with 120 patients undergoing laparoscopic surgeries. Patients were allocated into three groups: PEEP 0, PEEP 5 and PEEP 10. Lung ultrasound score (LUSS) was assessed preoperatively and postoperatively at 10, 30 and 60 minutes. Hemodynamic parameters and end tidal CO_2 were monitored.

Results: PEEP 5 maintained stable hemodynamics with significantly less atelectasis compared to PEEP 0 and PEEP 10. Mean LUSS was significantly lower in PEEP 5 (mean ±SD 7.5±2.1) compared to PEEP 0 (15.3±2.9) and PEEP 10 (8.1±2.6) ($p<0.001$). PEEP 5 maintained systolic blood pressure closer to baseline ($p<0.05$), while PEEP 10 caused significant hypotension.

Conclusion: This study concludes that a PEEP of 5 is optimal for minimizing postoperative atelectasis, as indicated by the Lung Ultrasound Score (LUSS), while also ensuring hemodynamic stability during laparoscopic surgeries.

Keywords: Positive end-expiratory pressure (PEEP), Lung ultrasound score (LUSS), Laparoscopic surgery, Pulmonary atelectasis, Pneumoperitoneum.

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1. Introduction

Laparoscopic surgeries offer benefits like shorter hospital stays, less pain and faster recovery but pose challenges due to increased intra-abdominal pressure (IAP).[1] Elevated IAP reduces functional residual capacity (FRC), promotes airway closure and increases atelectasis risk, necessitating oxygen supplementation.[2,3]

Pneumoperitoneum and steep Trendelenburg position further impair ventilation. Increased IAP and reduced abdominal wall compliance can compromise organ function, particularly in patients with comorbidities.[4,5] Volume-controlled ventilation maintains tidal volume but risks barotrauma, whereas pressure-controlled ventilation lowers peak pressures and improves alveolar recruitment. Positive end-expiratory pressure (PEEP) counteracts diaphragm displacement but must be carefully titrated to avoid reducing cardiac output.[6,7] Despite widespread use, the optimal intraoperative PEEP level remains a subject of debate, particularly in laparoscopic surgeries. Lower PEEP levels (0 cm H_2O) may be insufficient to prevent atelectasis, while higher levels (such as 10 cm H_2O) may impair venous return, leading to hemodynamic instability. A moderate PEEP of 5 cm H_2O is hypothesized to offer the best balance between improving lung aeration and preserving hemodynamic stability. Therefore, comparing these three levels—0, 5, and 10 cm H_2O—is clinically relevant to optimize patient outcomes during laparoscopic procedures.

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Lung ultrasonography is a valuable, non-invasive tool for monitoring lung aeration. The lung ultrasound score helps assess aeration changes and optimize PEEP levels, ensuring effective ventilation during laparoscopic surgery.[8] LUSS has shown good correlation with the development of pulmonary complications and postoperative hypoxemia.

The aim of this study was to compare the effects of different levels of positive end-expiratory pressure (0, 5, and 10 cm H_2O) on lung aeration in patients undergoing laparoscopic surgeries, as assessed by lung ultrasound scores, and to evaluate their impact on hemodynamic parameters and end-tidal CO_2 levels.

2. Materials and Methods

This study was a randomized controlled trial conducted over 12 months, after obtaining prior approval from the Institutional Ethical Committee and registration with the Clinical Trials Registry of India (CTRI No: CTRI/2024/03/064572). Written informed consent was obtained from all participants before recruitment. The study adhered to the CONSORT guidelines for clinical trials.

The study was conducted among 120 adult patients scheduled for laparoscopic surgery who were of age between 18 and 65 years, classified as ASA physical status I or II, and undergoing elective laparoscopic procedures lasting less than two hours. Participants with cardiopulmonary disorders, pregnancy, BMI <30, or a history of smoking were excluded from the study. Sample size of 40 for each group (PEEP 0, PEEP 5 and PEEP 10) was allotted, **Figure 1**). Randomization was performed using computer-generated random numbers and allocation concealment was maintained using sealed opaque envelopes.

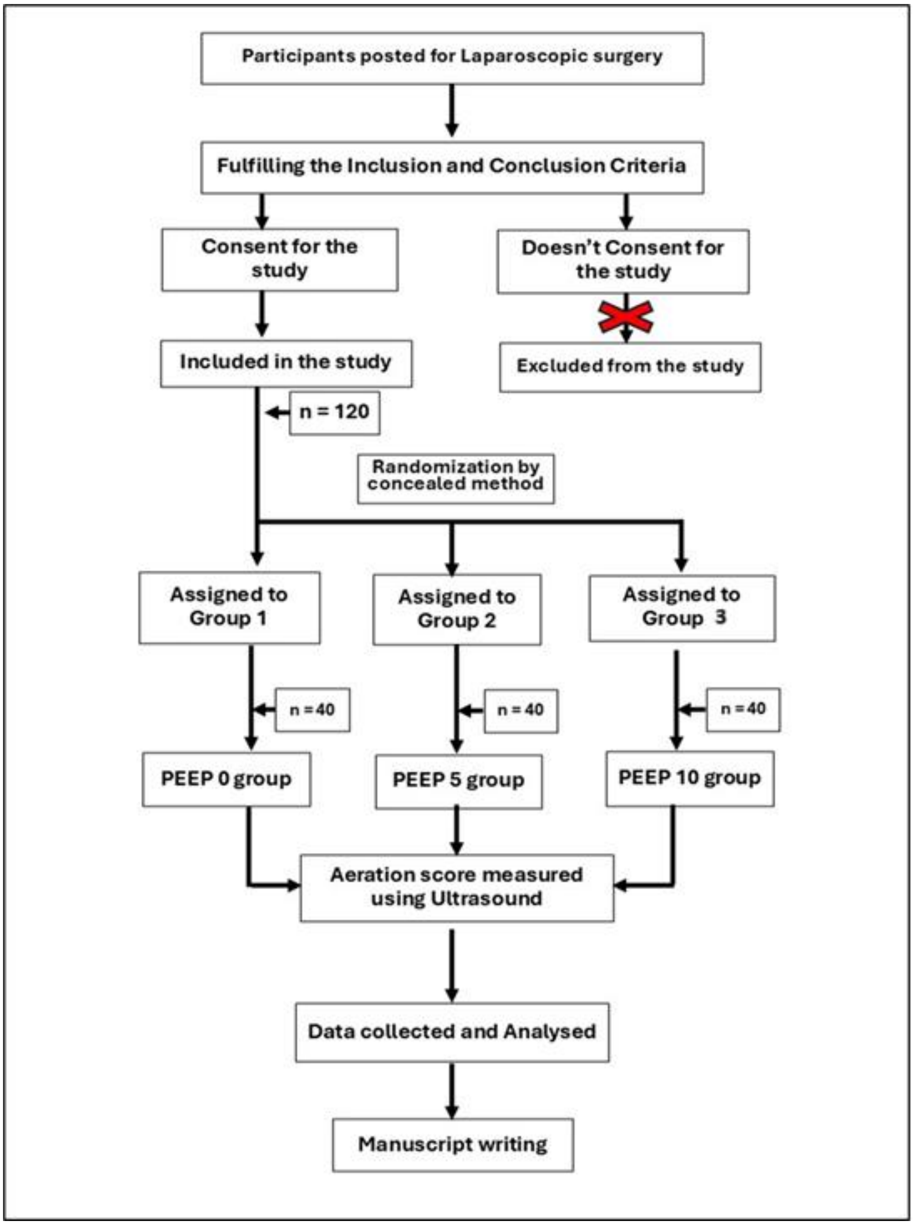

Figure 1: Consort flow chart

Upon participants arrival in the operating room, initial assessment such as pulse oximetry, electrocardiography (ECG), and non-invasive blood pressure (NIBP) measurement were done. Secondly Baseline lung aeration was assessed preoperatively using lung ultrasonography (LUS) in the supine position using a high-frequency linear probe (6–12 MHz). The thorax was divided into 12 regions, which are categorised into anterior, lateral and posterior regions based on anatomical landmarks covering the anterior axillary line, posterior axillary line, and horizontal areas beneath the nipple line bilaterally.[9-11]

Each lung was divided into six zones, totalling twelve regions for both lungs. The anterior region was defined by the sternum to the anterior axillary line, consisting of four zones—anterior superior and anterior inferior bilaterally. The lateral region spanned from the anterior axillary line to the posterior axillary line, comprising four zones—lateral superior and lateral inferior bilaterally. The posterior region covered from the posterior axillary line to the paravertebral line, with four zones—posterior superior and posterior inferior bilaterally.

The modified Lung Ultrasound Score System (LUSS) was used to quantify lung aeration loss, evaluating each intercostal space for changes indicating atelectasis or reduced aeration (**Figure 2**). Each lung region was scored from 0 to 3, and the total LUSS (ranging from 0 to 36) was calculated by summing the scores from all twelve zones.[12-13] Baseline LUSS was comparable across all groups ensuring that the initial lung aeration status was similar.

The interpretation of each lung region score was as follows:[14] A score of 0 indicated normal aeration loss, with a pleural line and A-lines present. A score of 1 represented mild aeration loss, characterized by a slightly irregular pleural line with sporadic vertical artifacts or minor white lung bands. A score of 2 indicated moderate aeration loss, with notable pleural line irregularities, predominance of B-lines, and small subpleural consolidations. Finally, a score of 3 signified severe aeration loss, with a highly irregular pleural line, extensive white lung, and larger consolidated areas.

The total LUSS and its interpretation were categorized as follows[15]: a score of 0-7 indicated normal or mild aeration loss, with few B-lines and minimal atelectasis; a score of 8-15 signified moderate aeration loss, with coalescent B-lines and small subpleural consolidation; and a score of 16-36 represented severe aeration loss or consolidation, with multiple coalescent B-lines, large consolidations, and significant loss of aeration.

All the patients were premedicated with intravenous glycopyrrolate (10 µg/kg), midazolam (0.05 mg/kg), and ondansetron (0.1 mg/kg). Anesthesia was induced with fentanyl (2 µg/kg), propofol (2–3 mg/kg), and atracurium (0.5 mg/kg). Endotracheal intubation was performed, and anesthesia was maintained with an oxygen-air mixture and sevoflurane. Each patient was ventilated according to the assigned PEEP level (0, 5, or 10 cm H_2O), while tidal volume and respiratory rate were kept within standard parameters. Intraoperative hemodynamic parameters, including heart rate, blood pressure, SpO_2, and $ETCO_2$, were continuously monitored. At the end of surgery, patients were assessed clinically and reversed with glycopyrrolate (10 mcg/kg) and neostigmine (0.03 mg/kg).

Postoperatively, lung aeration was assessed using lung ultrasound (LUS) at 10, 30, and 60 minutes in the recovery room. Intraoperative mechanical ventilation settings for PEEP 0, PEEP 5, and PEEP 10 were allocated for three different cases. Higher LUSS values were correlated with an increased risk of postoperative pulmonary complications, prolonged hospital stay, and impaired oxygenation.

For statistical analysis, the sample size was calculated to be 120 (40 in each group) based on a similar study by Kundra P et al.[16], with an effect size of 0.7. The level of significance and power were set at 5% and 80%, respectively. The formula used for the sample size calculation was:

$$n \geq (1+\sqrt{g-1})\frac{(Z_{1-\frac{\alpha}{2}}+Z_{1-\beta})^2}{(d)^2}+\frac{(Z_{1-\frac{\alpha}{2}})^2\sqrt{g-1}}{2(1+\sqrt{g-1})}$$

Where,
d is the effect size
g is the number of group
α is the level of significance
$1-\beta$ is the power

Continuous variables were analysed using ANOVA and t-tests. Categorial data were analyzed using Chi-squared or Fisher's exact tests. Statistical significance was set at $P<0.05$. Data analysis was performed using SPSS version 21.

3. Results

A total of 120 patients were enrolled and randomized equally into three groups (PEEP 0, PEEP 5, and PEEP 10), with 40 patients in each group. No participants were excluded at any point in the study. The CONSORT diagram depicting patient flow is shown in **Figure 1**. All groups were comparable regarding age, gender distribution, ASA physical status, and comorbidities (**Table 1**). However, statistically significant differences were observed in weight and height among the groups ($p<0.05$). Despite these differences, no correlation was found between anthropometric parameters (weight or height) and postoperative lung ultrasound scores (LUSS) or hemodynamic outcomes, minimizing their impact on the primary and secondary endpoints. Baseline lung aeration scores were comparable across groups ($p>0.05$), confirming the absence of pre-existing differences in lung status.

Systolic and diastolic blood pressures decreased significantly after intubation, prior to pneumoperitoneum, and after extubation across all groups (**Table 2)** The PEEP 10 group exhibited the most pronounced decrease in blood pressure compared to PEEP 0 and PEEP 5 groups ($p<0.05$). Similarly, heart rate increased significantly intraoperatively in the PEEP 10 group compared to the other groups ($p<0.05$), indicating hemodynamic instability. In contrast, the PEEP 5 group demonstrated more stable hemodynamic parameters throughout the perioperative period, suggesting better cardiovascular tolerance to moderate levels of PEEP.

Postoperative lung ultrasound scores (LUSS) at 10, 30, and 60 minutes were significantly different among the groups (**Table 3**). The PEEP 0 group had the highest mean LUSS values, indicating greater lung aeration loss and more frequent atelectasis. The PEEP 5 group achieved the lowest LUSS scores at all time points, reflecting better preservation of lung aeration without hemodynamic compromise. Mean ± SD LUSS values at 60 minutes were: PEEP 0: 15.3 ± 2.9, PEEP 5: 7.5 ± 2.1, and PEEP 10: 8.1 ± 2.6 ($p<0.001$ across groups). Although both PEEP 5 and PEEP 10 improved lung aeration compared to PEEP 0, PEEP 5 offered similar respiratory benefits with better hemodynamic stability compared to PEEP 10, underscoring its clinical superiority.

$EtCO_2$ levels increased after pneumoperitoneum across all groups but did not significantly differ between them ($p>0.05$). This suggests that while pneumoperitoneum influenced CO_2 levels, PEEP variations had minimal impact on ventilation-perfusion balance. At 10, 30, and 60 minutes, LUSS was significantly higher in the PEEP 0 group compared to PEEP 5 and PEEP 10 in the lateral zones ($p<0.001$) (**Figure 3**). In the posterior zones, at 60 minutes, posterior LUSS scores remained significantly higher in the PEEP 0 group ($p<0.001$) (**Figure 4**). No significant differences were observed at baseline, 10 minutes, and 30 minutes in the anterior zones; however, at 60 minutes, the PEEP 0 group demonstrated higher anterior aeration loss ($p<0.001$). Aeration scores (as seen as b lines in USG **Figure 5**) across PEEP groups were analyzed using repeated measures ANOVA with Bonferroni correction.

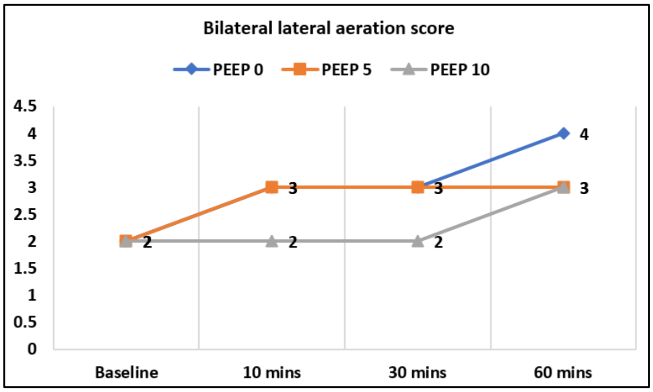

Figure 2: Comparison of bilateral lateral aeration score across groups

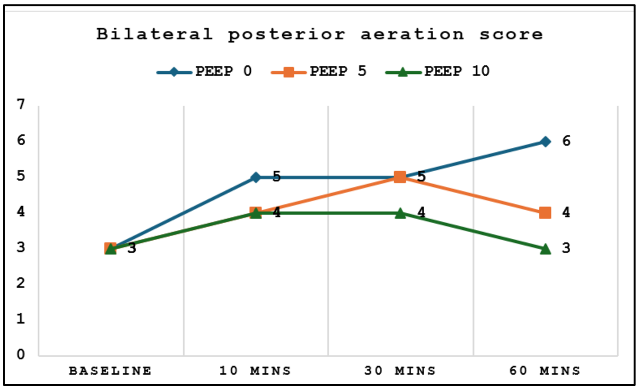

Figure 3: Comparison of bilateral posterior aeration score across groups

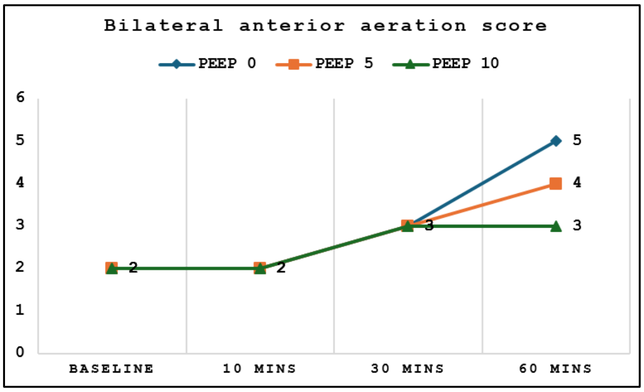

Figure 4: Comparison of bilateral anterior score across groups

Figure 5: Lung ultrasound showing b-lines

Table 1: Demographic characteristics of study participants

Variable	PEEP 0 (n=40)	PEEP 5 (n=40)	PEEP 10 (n=40)	Total (n=120)	p-value
Age (years)					0.172
<20	4 (10.0%)	0 (0.0%)	0 (0.0%)	4 (3.3%)	
20-40	15 (37.5%)	17 (42.5%)	17 (42.5%)	49 (40.8%)	
40-60	14 (35.0%)	18 (45.0%)	17 (42.5%)	49 (40.8%)	
>60	7 (17.5%)	5 (12.5%)	6 (15.0%)	18 (15.0%)	
Gender					0.964
Female	15 (37.5%)	14 (35.0%)	14 (35.0%)	43 (35.8%)	
Male	25 (62.5%)	26 (65.0%)	26 (65.0%)	77 (64.2%)	
Comorbidities					0.251
Hypertension	17 (42.5%)	18 (45.0%)	13 (32.5%)	48 (40.0%)	
Diabetes Mellitus	17 (42.5%)	8 (20.0%)	16 (40.0%)	41 (34.2%)	
Hypothyroidism	1 (2.5%)	2 (5.0%)	1 (2.5%)	4 (3.3%)	
No Comorbidity	5 (12.5%)	12 (30.0%)	10 (25.0%)	27 (22.5%)	
ASA Grade					0.177
ASA I	6 (15.0%)	13 (32.5%)	11 (27.5%)	30 (25.0%)	
ASA II	34 (85.0%)	27 (67.5%)	29 (72.5%)	90 (75.0%)	
Anthropometry (Mean ± SD)					
Height (cm)	155.2 ± 8.8	156.3 ± 6.7	157.7 ± 7.3	-	0.345
Weight (kg)	65.2 ± 6.6	65.9 ± 5.6	68.1 ± 7.4	-	0.121
BMI (kg/m^2)	27.1 ± 1.6	26.9 ± 1.3	27.2 ± 1.9	-	0.716

Table 2: Hemodynamic parameters

Time Point	PEEP 0 (Mean ± SD)	PEEP 5 (Mean ± SD)	PEEP 10 (Mean ± SD)	p-value
Systolic BP (mmHg)				
Baseline	122 ± 8.7	124 ± 9.5	123 ± 7.2	0.666
After Intubation	130 ± 13.1	120 ± 10.8	115 ± 7.3	<0.001
Before Pneumoperitoneum	122 ± 12	110 ± 12	100 ± 10.2	<0.001
After Pneumoperitoneum	132 ± 7.9	120 ± 12.3	100 ± 12	<0.001
Before Extubation	120 ± 9.8	100 ± 10.1	90 ± 10.1	<0.001
Post-op 60 mins	123 ± 10	113 ± 10.5	100 ± 7.4	0.030
Diastolic BP (mmHg)				
Baseline	83.0 ± 8.2	82.0 ± 9.7	78.0 ± 10.5	0.068
After Intubation	100.0 ± 12.3	90.0 ± 9.8	80.0 ± 13.6	<0.001
Before Pneumoperitoneum	93.0 ± 9.1	75.0 ± 7.4	68.0 ± 12.7	<0.001
After Pneumoperitoneum	100.0 ± 10.1	80.0 ± 10.8	60.0 ± 9.9	<0.001
Before Extubation	80.0 ± 8.3	60.0 ± 9.4	50.0 ± 7.9	<0.001
Post-op 60 mins	80.0 ± 9.5	70.0 ± 10.3	50.3 ± 8.8	0.042
Heart Rate (beats per minute)				
Baseline	80.8 ± 11.6	79.2 ± 11.9	79.5 ± 9.3	0.465
After Intubation	90.8 ± 11.7	95.2 ± 10.1	98.5 ± 8.5	0.041
Before Pneumoperitoneum	92.8 ± 10.2	96.2 ± 10.2	98.5 ± 8	0.037
After Extubation	90.8 ± 11.6	95.2 ± 8.1	100.5 ± 12.2	0.002
Post-op 60 mins	77.5 ± 12.6	89.7 ± 13	90.0 ± 8.7	0.031

Table 3: Comparison of total LUSS across groups

Total Luss		Median	IQR	p-value
Baseline	PEEP 0	8	6	0.143
	PEEP 5	8	5	
	PEEP 10	8	6	
10 mins	PEEP 0	10	7	0.001
	PEEP 5	9	5	
	PEEP 10	9	6	
30 mins	PEEP 0	11	8	0.021
	PEEP 5	10	5	
	PEEP 10	9	5	
60 mins	PEEP 0	14	6	<0.001
	PEEP 5	11	5	
	PEEP 10	10	6	

4. Discussion

The study found that the average age of participants was 43.3 years, with a majority being middle-aged males. Our findings align with previous research by Srivastava A et al. and Östberg E et al., which demonstrated that moderate PEEP ≤ 5 cm H_2O effectively reduces postoperative atelectasis without causing significant hemodynamic compromise.[17,18] (17,18) The need for PEEP intervention was more prevalent in older males, which is consistent with earlier studies suggesting that aging and male sex predispose individuals to respiratory complications during surgeryintervention was more common in older males, consistent with previous studies.[19,20]

Blood pressure remained stable at baseline but significantly dropped in the PEEP 5 and PEEP 10 groups after intubation, pneumoperitoneum, extubation, and postoperatively, with the most pronounced decline observed in the PEEP 10 group. PEEP 10 resulted in hypotension and tachycardia, which can be attributed to reduced venous return from the elevated intrathoracic pressure. This mechanism is well understood: high PEEP increases intrathoracic pressure, compresses the vena cava, reduces preload, and consequently decreases cardiac output, leading to hypotension and reflex tachycardia.[21,22] These findings support the hypothesis that higher PEEP levels, while beneficial for lung aeration, may have detrimental effects on circulatory dynamics, particularly in patients with limited cardiovascular reserve.

Heart rate remained stable at baseline but increased during surgery, with a significant rise observed across PEEP groups at key surgical stages. Interestingly, the heart rate returned to normal postoperatively in all groups. Higher PEEP levels helped stabilize cardiac function and improve arterial oxygenation, as reported in other studies.[23] This highlights that moderate PEEP levels not only aid in improving lung mechanics but may also contribute to maintaining overall cardiac stability during laparoscopic procedures.

$EtCO_2$ levels were lowest immediately after intubation and peaked after pneumoperitoneum, with no significant differences across the PEEP groups. This suggests that pneumoperitoneum had a more pronounced impact on $EtCO_2$ than PEEP, likely due to the fact that PEEP primarily modifies alveolar recruitment rather than influencing CO_2 elimination to a large extent. Therefore, PEEP variations had minimal influence on the ventilation-perfusion balance during surgery.[23]

Lung ultrasound scores (LUSS) were initially similar across all groups but showed significantly lower scores in the PEEP 5 and PEEP 10 groups postoperatively. This indicates better lung aeration and reduced atelectasis in these groups, particularly in the PEEP 5 group, which showed the most favourable outcome. Higher PEEP levels improve alveolar recruitment and reduce postoperative lung collapse, but excessive PEEP may pose a risk for lung overdistension, which has been associated with ventilator-associated lung injury.[24,25] These findings suggest that individualized PEEP titration, tailored to each patient's specific needs, is crucial for optimising lung function without compromising other physiological parameters.

Hemodynamic fluctuations were more common in the PEEP 0 and PEEP 10 groups, whereas PEEP 5 maintained more stable cardiovascular function. PEEP 10, while improving lung aeration, led to reduced venous return and cardiac output, causing hypotension and tachycardia. On the other hand, PEEP 0 resulted in hypoxemia-related instability, particularly in patients with already compromised lung function. PEEP 5 provided a balanced response, optimizing both lung function and circulatory stability, which emphasizes the importance of choosing the appropriate PEEP level for individual patients.

No participants in this study developed complications such as barotrauma, pneumothorax, or subcutaneous emphysema, which further supports the safety of PEEP levels between 0 and 10 cm H_2O when applied with appropriate ventilation strategies. Moderate PEEP levels (PEEP 5) appeared to offer the best balance between lung aeration and hemodynamic stability, as it diminished the risks associated with both higher and lower PEEP settings.

While the application of PEEP is crucial for optimizing lung aeration in laparoscopic surgeries, the findings from this study highlight the importance of individualized PEEP titration to avoid the negative impact on cardiovascular stability. Further research, employing standardized methods and exploring different patient populations, is needed to refine PEEP strategies and establish optimal guidelines for intraoperative ventilation. However, the study had a relatively small sample size, focused primarily on middle-aged males, and lacked long-term follow-up, meaning the sustained effects of PEEP on pulmonary function postoperatively were not assessed. Future studies with larger, more diverse populations and extended follow-up periods are necessary to confirm these findings and explore long-term outcomes.

5. Conclusion

This study concludes that applying moderate positive end-expiratory pressure (PEEP) at 5 cm H_2O effectively reduces postoperative lung atelectasis while maintaining hemodynamic stability during laparoscopic surgeries. While higher PEEP levels (10 cm H_2O) improved lung aeration, they were associated with significant hemodynamic compromise, and no PEEP (0 cm H_2O) increased the risk of atelectasis. Individualized PEEP optimization, particularly at 5 cm H_2O, enhances pulmonary outcomes and improves patient safety in laparoscopic surgical settings.

6. Source of Funding

None.

7. Conflict of Interest

None.

References

1. Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME. Debas HT. DCP3 Essential surgery author group essential surgery: key messages from disease control priorities. *Lancet.* 2015;385(9983):2209–19.
2. Saraswat V. Effects of anaesthesia techniques and drugs on pulmonary function. *Indian J Anaesth.* 2015;59(9):557–64.
3. Hedenstierna G, Edmark L. Effects of anesthesia on the respiratory system. *Best Pract Res Clin Anaesthesiol*. 2015;29(3):273–84.
4. Hayden P, Cowman S. Anaesthesia for laparoscopic surgery. *Contin Educ Anaesth Crit Care Pain*. 2011;11(5):177–80.
5. Bajwa SJ, Kulshrestha A. Anaesthesia for laparoscopic surgery: General vs regional anaesthesia. *J Min Access Surg*. 2016;12(1):4–9.
6. Civraz AZ, Saracoglu A, Saracoglu KT. Evaluation of the effect of pressure-controlled ventilation-volume guaranteed mode vs. volume-controlled ventilation mode on atelectasis in patients undergoing laparoscopic surgery: a randomized controlled clinical trial. *Medicina.* 2023;59(10):1783.
7. Li X, Liu H, Wang J, Ni ZL, Liu ZX, Jiao JL, et al. Individualized positive end-expiratory pressure on postoperative atelectasis in patients with obesity: a randomized controlled clinical trial. A*nesthesiology*. 2023;139(3):262–73.
8. Zimatore C, Algera AG, Botta M, Pierrakos C, Serpa Neto A, Grasso S, et al. Lung ultrasound to determine the effect of lower vs. higher peep on lung aeration in patients without ARDS-A substudy of a randomized clinical trial. *Diagnostics (Basel)*. 2023;13(12):1989.
9. Todur P, Care SC, Care VA, Srikant N, Prakash P. Correlation of oxygenation and radiographic assessment of lung edema (RALE) score to lung ultrasound score (LUS) in acute respiratory distress syndrome (ARDS) patients in the intensive care unit. *Can J Respir Ther.* 2021;57:53–9.
10. Smit MR, Hagens LA, Heijnen NF, Pisani L, Cherpanath TG, Dongelmans DA, et al. Lung ultrasound prediction model for acute respiratory distress syndrome: a multicenter prospective observational study. *Am J Respir Crit Care Med*. 2023;207(12):1591–601.
11. Curry S, Tan A, Gargani L, Ng O, Roscoe A, Salaunkey K, et al. Lung ultrasound and the role of lung aeration score in patients with acute respiratory distress syndrome on extracorporeal membrane oxygenation. *Int J Artif Organs.* 2021;44(11):854–60.
12. Pereira SM, Tucci MR, Morais CC, Simões CM, Tonelotto BF, Pompeo MS, et al. Individual positive end-expiratory pressure settings optimize intraoperative mechanical ventilation and reduce postoperative atelectasis. *Anesthesiology*. 2018;129(6):1070–81.
13. Speidel V, Conen A, Gisler V, Fux CA, Haubitz S. Lung assessment with point-of-care ultrasound in respiratory coronavirus disease (COVID-19): a prospective cohort study. *Ultrasound Med Biol.* 2021;47(4):896–901.
14. Mojoli F, Bouhemad B, Mongodi S, Lichtenstein D. Lung ultrasound for critically ill patients. *Am J Respir Crit Care Med.* 2019;199(6):701–14.
15. Demi L, Wolfram F, Klersy C, De Silvestri A, Ferretti VV, Muller M, et al. New international guidelines and consensus on the use of lung ultrasound. *J Ultrasound Med.* 2023;42(2):309–44.
16. Kundra P, Subramani Y, Ravishankar M, Sistla SC, Nagappa M, Sivashanmugam T. Cardiorespiratory effects of balancing PEEP with intra-abdominal pressures during laparoscopic cholecystectomy. *Surg Laparosc Endosc Percutaneous Tech.* 2014;24(3):232–9.
17. Srivastava A, Niranjan A. Secrets of safe laparoscopic surgery: Anaesthetic and surgical considerations. *J Min Access Surg.* 2010;6(4):91–4.
18. Östberg E, Thorisson A, Enlund M, Zetterström H, Hedenstierna G, Edmark L. Positive end-expiratory pressure and postoperative atelectasis: a randomized controlled trial. *Anesthesiology.* 2019;131(4):809–17.
19. Atashkhoei S, Yavari N, Zarrintan M, Bilejani E, Zarrintan S. Effect of different levels of positive end-expiratory pressure (PEEP) on respiratory status during gynecologic laparoscopy. A*nesthesiol Pain Med*. 2020;10(2)\:e100075.
20. Szabó M, Bozó A, Darvas K, Soós S, Őzse M, Iványi ZD. The role of ultrasonographic lung aeration score in the prediction of postoperative pulmonary complications: an observational study. *BMC Anesthesiol.* 2021;21:19.
21. Meininger D, Byhahn C, Mierdl S, Westphal K, Zwissler B. Positive end-expiratory pressure improves arterial oxygenation during prolonged pneumoperitoneum. *Acta Anaesthesiol Scand*. 2005;49(6):778–83.
22. Abedinzade M, Taghavi N, Farsani NM. Evaluation of the effects of gradual increases in intra-abdominal pressure on blood pressure in a patient undergoing laparoscopic cholecystectomy. 2024;10.21203/rs.3.rs-4601648/v1.
23. Atashkhoei S, Yavari N, Zarrintan M, Bilejani E, Zarrintan S. Effect of different levels of positive end-expiratory pressure (PEEP) on respiratory status during gynecologic laparoscopy. *Anesthesiol Pain Med*. 2020;10(2)\:e100075.
24. Kim BR, Lee S, Bae H, Lee M, Bahk JH, Yoon S. Lung ultrasound score to determine the effect of fraction inspired oxygen during

alveolar recruitment on absorption atelectasis in laparoscopic surgery: a randomized controlled trial. *BMC Anesthesiol.* 2020;20:1–1.

25. Deeparaj L, Kumar R, Patel N, Ayub A, Rewari V, Subramaniam R, et al. Effect of lung compliance-based optimum pressure versus fixed positive end-expiratory pressure on lung atelectasis assessed by modified lung ultrasound score in laparoscopic gynecological surgery: A prospective randomized controlled trial. *Cureus*. 2023;15(6):e40278.

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