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Lung ultrasound guided positive end expiratory pressure adjustment in enhanced recovery program based laparoscopic bariatric surgery: a prospective, randomized controlled trial

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Abstract

Objective: This prospective study aims to evaluate the effectiveness of lung ultrasound-guided positive end-expiratory pressure (PEEP) adjustment in optimizing respiratory mechanics and enhancing recovery in patients undergoing laparoscopic bariatric surgery within an enhanced recovery program (ERP).

Methods: Patients scheduled for laparoscopic bariatric surgery within an ERP were enrolled. Lung ultrasound was performed preoperatively and intraoperatively to assess lung recruitment and optimize PEEP levels. Respiratory parameters, including oxygenation indices and ventilatory mechanics, were monitored throughout the perioperative period. Postoperative outcomes, including pulmonary complications, and overall recovery, were assessed.

Results: The study initially included 54 patients but excluded seven due to an ASA score greater than III, with additional exclusions for decompensated cardiac disease and hemodynamic instability, leaving 40 patients divided into two groups of 20 each. Demographic and health risk factors, including age, gender, BMI, smoking status, ASA classification, and STOP-BANG scores, showed no significant differences between the Control and Study groups, ensuring comparability. While baseline peripheral oxygen saturation (SpO2) levels were similar, significant differences emerged at the 30-minute mark during surgery, with the Study group exhibiting higher SpO2 levels (99.08% vs. 97.04%, $p < 0.001$). Lung ultrasound scores revealed that the Control group had worsened lung function postoperatively, while the Study group showed improvements. Repeated measures ANOVA confirmed these findings as statistically significant. Postoperative pulmonary complications were significantly lower in the Study group, with reduced rates of atelectasis (24% vs. 76%) and hypoxia (20% vs. 28%), though no difference in pneumothorax rates was observed, highlighting the efficacy of PEEP adjustments based on lung ultrasound in improving postoperative outcomes.

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Conclusion: Lung ultrasound-guided PEEP adjustment represents a promising approach for optimizing respiratory function and enhancing recovery in patients undergoing laparoscopic bariatric surgery within an ERP. Further studies are warranted to validate these findings and establish standardized protocols for its implementation in clinical practice.

Keywords: Lung, Ultrasound, PEEP, Bariatric Surgery.

Introduction

Laparoscopic bariatric surgery has transformed the approach to treating obesity and its related conditions, offering patients a minimally invasive option with faster recovery times.[1] However, maintaining optimal respiratory function throughout the perioperative period remains a significant challenge. Obese individuals often face compromised respiratory mechanics, increasing their vulnerability to postoperative pulmonary complications such as atelectasis and pneumonia.[2] Thus, there is a critical need to address respiratory management strategies during laparoscopic bariatric surgery.

Positive end-expiratory pressure (PEEP) plays a vital role in mechanical ventilation, particularly in the context of laparoscopic bariatric surgery, where altered respiratory mechanics and pneumoperitoneum-induced changes in lung compliance are common.[3] Proper PEEP management aims to prevent alveolar collapse, optimize oxygenation, and improve lung compliance, thereby reducing the risk of postoperative pulmonary complications.[4] Integrating evidence-based interventions, such as lung ultrasound, into enhanced recovery programs (ERPs) for bariatric surgery shows promise in further enhancing patient outcomes by providing real-time feedback on lung recruitment and aeration to guide ventilator management, including PEEP adjustment.[5]

Despite the growing body of literature supporting the use of lung ultrasound in various clinical settings, its application within an ERP for laparoscopic bariatric surgery remains relatively unexplored.[6] The present study is a prospective study that aims to investigate the impact of lung ultrasound-guided PEEP adjustment on respiratory mechanics, perioperative outcomes, and overall recovery in patients undergoing laparoscopic bariatric surgery within an ERP. By integrating lung ultrasound into perioperative management, the study seeks to optimize respiratory function, minimize postoperative complications, and further improve the benefits of laparoscopic bariatric surgery within an ERP framework.

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Patients and methods

After gaining the approval of the Institutional Review Board (No. 00012098), registration at the ClinicalTrials. (PACTR202205833785538) and informed written consent from each patient, we studied 50 adult patients aged 18 to 65 years with American Society of Anesthesiologists (ASA) physical status II or III undergoing laparoscopic bariatric surgery at Alexandria Main University Hospital. Patients were divided into two groups: the control group received a fixed intraoperative PEEP of 5 cmH2O, while the study group had PEEP adjusted based on lung ultrasound findings. Inclusion criteria were stringent, including adherence to surgery requirements, while exclusion criteria encompassed factors like patient refusal and certain comorbidities.

The study followed the ERAS program guidelines, including pre-admission preparation and preoperative medication. On the day of surgery, patients underwent specific preparations such as carbohydrate loading and received medications like dexamethasone and ranitidine. Intraoperatively, anesthesia was administered according to protocol, with mechanical ventilation and fluid therapy. Lung ultrasound guided PEEP adjustments in the study group, aiming for optimal lung recruitment.

Postoperative care involved various interventions like analgesia and early mobilization, with discharge criteria ensuring patient readiness for home recovery. Throughout the study, care providers were unaware of patient group assignments, maintaining the integrity of the research design.

Results

The original sample size was 54 individuals. Seven patients were initially excluded due to having an ASA score greater than III. Among these, five patients were further excluded due to decompensated cardiac disease, and an additional two were excluded due to hemodynamic instability. The remaining 40 patients were then divided into two groups: Group 1 with 20 participants and Group 2 with 20 participants. This sequential selection process ensures that participants meet predetermined criteria for inclusion in the study, thereby enhancing the reliability and validity of the research findings.

The study compared demographic characteristics between a Control group and a Study group undergoing laparoscopic bariatric surgery. The Control group had a mean age of 32.16 years, while the Study group had a mean age of 33.62 years. Both groups comprised 24 male and 26 female patients. Regarding BMI, the Control group had a mean BMI of 38.17 kg/m2, while the Study group had a mean BMI of 37.24

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kg/m2. Statistical analysis showed no significant difference in age, gender distribution, or BMI between the Control and Study groups.

The study compared patient characteristics and health risk factors between both study groups. In the Control group, 32% were smokers, and 68% were non-smokers, while in the Study group, 16% were smokers and 84% were non-smokers. ASA classification revealed that 64% of the Control group and 72% of the Study group were classified as ASA III, indicating severe systemic disease. STOP-BANG scores, assessing obstructive sleep apnea risk, ranged from 0 to 8 in both groups, with a majority exhibiting scores above 2, indicating moderate to high risk. Statistical analysis showed no significant difference in patient characteristics and health risk factors between the Control and Study groups.

Regarding perioperative peripheral oxygen saturation (SpO_2), at the baseline, the control group exhibited a mean peripheral oxygen saturation of 97.2 ± 0.2 (%), while the study group had a mean of 97.76 ± 0.6 (%), with no statistically significant difference between the groups at this initial stage. Subsequent time points were assessed, including 5 minutes after Mechanical Ventilation (MV) and 5 minutes after pneumoperitoneum (Figure 1).

Both groups showed minimal changes in oxygen saturation levels, with no statistically significant differences observed ($p > 0.05$). Similarly, after 15 minutes, the groups demonstrated comparable saturation levels, with a p-value of 0.76 confirming no significant distinction between them. However, as the surgical procedure progressed, substantial differences emerged. Notably, at the 30-minute mark, the control group displayed a mean saturation of 97.04 ± 0.74 (%), while the study group exhibited a higher mean of 99.08 ± 0.49 (%). The p-value was less than 0.001, indicating a statistically significant difference in oxygen saturation between the groups.

The study examined the Lung Ultrasound Score for Consolidation and Aeration in both a control group and a study group undergoing surgery. The control group showed varying degrees of consolidation and aeration at baseline, with changes occurring postoperatively, including increased consolidation and decreased aeration immediately after surgery and continuing into the first postoperative day. Conversely, the study group exhibited fluctuations in lung ultrasound scores during intraoperative stages but showed potential improvements in lung aeration by the end of surgery. The systematic approach for lung ultrasound screening outlined regular screening protocols and monitoring frequencies, with adjustments in positive end-expiratory pressure (PEEP) based on lung ultrasound scores to optimize lung function.

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Significant differences emerged between the control and study groups postoperatively, with the control group experiencing worsened lung function while the study group showed improvements (Table 1). Statistical analyses, including repeated measures ANOVA, confirmed these differences as statistically significant, suggesting that observed variations were not due to random variability. The p-value being less than 0.05 indicated the significance of these findings, highlighting the potential utility of lung ultrasound scores in assessing lung function preoperatively and monitoring changes postoperatively (Table 2).

Table 3 presents postoperative pulmonary complications observed in both groups. A significant difference was noted between the groups, with Group 2 demonstrating notably lower rates of atelectasis (24.0% vs. 76.0%) and hypoxia (20.0% vs. 28.0%) compared to Group 1. However, there was no significant difference in pneumothorax occurrence between the two groups. These findings suggest that adjusting intraoperative PEEP based on lung ultrasound may reduce the incidence of postoperative pulmonary complications in patients undergoing laparoscopic bariatric surgery.

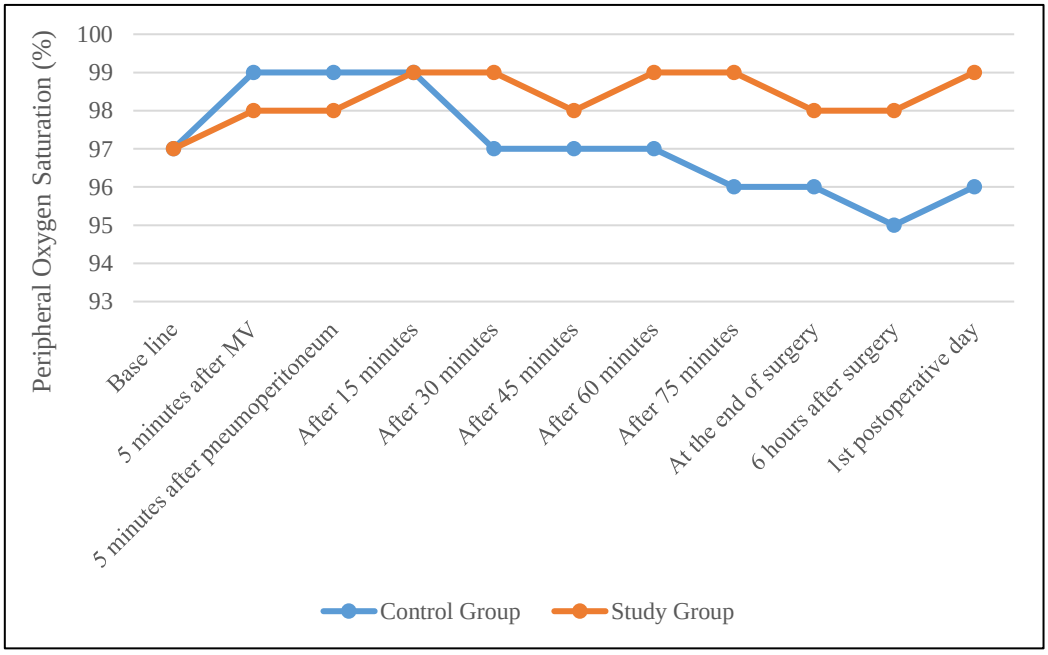

Figure 1 - Peripheral oxygen saturation (SpO_2) of both groups.

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Table 1 - Comparison Between Both Groups According to The Lung Ultrasound Score of Consolidation and Aeration.

Lung ultrasound score of consolidation and aeration	Control Group	Study Group	t	*p*
	Mean ± SD	Mean ± SD		
Base line	1.08 ± 0.50	1.04 ± 0.88	1.38	0.22
6 hours after surgery	1.44 ± 0.51	0.36 ± 0.77	4.27*	0.001*
1st postoperative day	1.52 ± 0.51	0.32 ± 0.77	3.62*	0.01*

(t) Student t-test; (p) value of probability

Table 2 - Repeated Measures Analysis of Variance (ANOVA) for Lung Ultrasound Scores in group 2 patients; Study group.

	df	sum_sq	mean_sq	F	PR(>F)
Variable	10.0	6.56	0.656000	0.987141	0.0454893
Residual	264.0	175.44	0.664545	NaN	NaN

(df) Degrees of Freedom; (sum_sq) Sum of Squares; (mean_sq) Mean Squares; (F) F-statistic; (PR(>F)) p value (Probability of F-statistic)

Table 3 - Postoperative pulmonary complications in both groups.

Postoperative Pulmonary Complications	Control Group		Study Group		x^2	*p*
	Number	%	Number	%		
Atelectasis	19	76.0	6	24.0	183	<0.001*
Hypoxia	7	28.0	5	20.0	154	<0.001*
Pneumothorax	0	0.0	1	3.0	114	0.62

(%) percentage; (x^2) chi-square test; (p) value of probability; (*) statistically significant value.

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Discussion

The study emphasizes the importance of perioperative monitoring and intervention strategies to optimize lung function in surgical patients. Utilizing lung ultrasound screening for real-time assessment of lung aeration and consolidation is highlighted as a promising approach to promptly identify and address changes in respiratory status. Initially, both the Control and Study groups showed no significant differences in baseline characteristics, ensuring a balanced comparison in terms of age, gender distribution, BMI, and health risk factors.

Significant differences emerged regarding perioperative peripheral oxygen saturation (SpO_2), with the Study group exhibiting higher levels compared to the Control group as the surgical procedure progressed. Analysis of lung ultrasound scores revealed postoperative lung function differences between the two groups. While the Control group experienced worsened lung function postoperatively, the Study group showed potential improvements in lung aeration by the conclusion of surgery, indicating the potential benefits of the study intervention in preserving or enhancing lung function.

Statistical analyses supported the observed differences in lung function between the Control and Study groups, confirming the clinical relevance of the study intervention in mitigating postoperative pulmonary complications. Individualizing intraoperative positive end-expiratory pressure (PEEP) based on lung ultrasound assessments was found to significantly reduce complications like atelectasis and hypoxia, suggesting that optimizing intraoperative ventilation based on real-time lung assessments could improve respiratory outcomes.

In agreement with the obtained results, ***Liu T. et al.***[7] conducted a study examining the impact of perioperative lung ultrasound-guided recruitment manoeuvres combined with positive end-expiratory pressure on postoperative atelectasis and hypoxemia in major open upper abdominal surgery. They found that ventilation strategies lacking PEEP or with PEEP alone didn't effectively reduce postoperative pulmonary complications. However, employing PEEP of 5 cmH_2O alongside LUS-guided recruitment manoeuvres notably decreased the incidence of atelectasis and hypoxemia. This underscores the potential advantages of integrating LUS guidance into ventilation strategies to optimize postoperative outcomes in major open upper abdominal surgeries.

Although there was no notable difference in pneumothorax occurrence between the study and control groups, the absence of increased risk with personalized PEEP adjustment suggests its safety. These findings have implications beyond the

study's immediate scope, particularly in improving surgical outcomes, especially in high-risk surgeries like bariatric procedures. The observed improvements in oxygen saturation and lung function suggest the potential for tailored interventions to optimize perioperative care and enhance postoperative recovery.

Cylwik J. et al.[8] conducted a study targeting postoperative respiratory failure by optimizing recruitment maneuvers using chest ultrasonography during general anesthesia. The method effectively reduced atelectasis in 91.9% of patients, with an average PEEP of 17 cmH_2O required to reverse atelectasis and 9 cmH_2O to prevent its recurrence. This approach resulted in significant enhancements in lung compliance and saturation. The findings suggest that ultrasound-guided recruitment maneuvers enable personalized adjustments, reducing ventilation pressures needed for intraoperative atelectasis while lowering associated complication risks.

Furthermore, the utilization of lung ultrasound scores as a tool for assessing and monitoring postoperative lung function represents a novel approach with promising clinical applications. By providing real-time information on lung aeration and consolidation, lung ultrasound can aid clinicians in identifying early signs of pulmonary complications and implementing timely interventions to mitigate adverse outcomes.

Limitations of the Study

- **Single-Center Study:** The study was conducted at a single institution, Alexandria Main University Hospital. Results may vary in different clinical settings with diverse patient populations and varying surgical and anesthetic practices.
- **Intervention Complexity:** Implementing lung ultrasound-guided PEEP adjustment requires additional training and resources, which may not be readily available in all clinical settings. This could affect the feasibility of adopting this intervention widely.
- **Potential Confounding Factors:** Despite randomization, there may still be unmeasured confounding factors that could influence the outcomes, such as differences in intraoperative care or postoperative management that were not controlled for in the study.

Conclusions

In conclusion, the study's findings shed light on the dynamic changes in lung function following bariatric surgery and highlight the potential benefits of

incorporating lung ultrasound into perioperative management protocols. Further research is warranted to elucidate the underlying mechanisms driving these observed changes and to evaluate the long-term impact on clinical outcomes. By leveraging innovative techniques such as lung ultrasound and adopting personalized perioperative management strategies, clinicians can strive to enhance the safety and efficacy of surgical care for patients undergoing bariatric surgery.

Conflicts of interest

The authors declared no conflicts of interest.

References

1. Sundbom M. Laparoscopic revolution in bariatric surgery. World J Gastroenterol. 2014;20(41):15135-43.
2. Hodgson LE, Murphy PB, Hart N. Respiratory management of the obese patient undergoing surgery. J Thorac Dis. 2015;7(5):943-52.
3. Bae HB. Application of positive end expiratory pressure during laparoscopic surgery. Korean J Anesthesiol. 2013;65(3):193-4.
4. Zhou ZF, Fang JB, Wang HF, He Y, Yu YJ, Xu Q, et al. Effects of intraoperative PEEP on postoperative pulmonary complications in high-risk patients undergoing laparoscopic abdominal surgery: study protocol for a randomised controlled trial. BMJ Open. 2019;9(10):e028464.
5. Agnoletti V, Bonilauri S, De Pietri L, Ferrara D, Lanaia A, Pipia N, et al. Implementation of an Enhanced Recovery Program After Bariatric Surgery: clinical and cost-effectiveness analysis. Acta Clin Croat. 2020;59(2):227-32.
6. Elshazly M, Khair T, Bassem M, Mansour M. The use of intraoperative bedside lung ultrasound in optimizing positive end expiratory pressure in obese patients undergoing laparoscopic bariatric surgeries. Surg Obes Relat Dis. 2021;17(2):372-8.
7. Liu T, Huang J, Wang X, Tu J, Wang Y, Xie C. Effect of recruitment manoeuvres under lung ultrasound-guidance and positive end-expiratory pressure on postoperative atelectasis and hypoxemia in major open upper abdominal surgery: A randomized controlled trial. Heliyon. 2023;9(2):e13348.
8. Cylwik J, Buda N. Lung Ultrasonography in the Monitoring of Intraoperative Recruitment Maneuvers. Diagnostics (Basel). 2021;11(2).