RCT ARTICLE

Comparison of pressure support and manual ventilation modes during anaesthesia emergence on postoperative atelectasis using lung ultrasonography: A prospective cohort study

Busra Otlu Biyikoglu, Bulent Serhan Yurtlu, Volkan Hanci, Ali Salih Biyikoglu

Abstract

Objective: To investigate the effects of different ventilatory approaches during the recovery phase of anaesthesia on the incidence of atelectasis.

Method: The prospective cohort study was conducted from August to November 2022 at Dokuz Eylul University Hospital, Izmir, Turkiye, and comprised patients aged at least 18 years with an American Society of Anaesthesiologists physical status classification of I-III who were undergoing elective ophthalmic surgery, extremity surgeries, or septorhinoplasty procedures under general anaesthesia with endotracheal intubation for a duration of 1-3 hours. The patients were divided into pressure support ventilation group A and manual ventilation group B. Lung ultrasonography was performed preoperatively and postoperatively using a lung transthoracic ultrasound score system ranging 0-36. Degree of atelectasis in each lung region was rated on a 0-3 scale, and a total score was computed for every patient. Patients with a total score 0 were classified as having no atelectasis, while those with a score of 1 or higher were classified as having atelectasis. Data was analysed using SPSS 25.

Results: Of the 2878 patients, 139(50%) were in group A; 72(51.8%) males and 67(48.2%) females with overall mean age 45.4±19.1 years. The remaining 139(50%) were in group B; 71(51.1%) males and 68(48.9%) females with overall mean age 49.7±18.6 years (p>0.05). The total postoperative lung ultrasonography median values were 1 (interquartile range: 0-3) in group A and 2(interquartile range: 0-4) in group B (p=0.041). Atelectasis was present in 106(76%) patients in group B compared to 84(60%) patients in group A (p=0.005).

Conclusion: In patients who received pressure support ventilation, a lower incidence of postoperative atelectasis was observed, suggesting that pressure support ventilation may be a more effective ventilation method in the postoperative period.

ClinicalTrials.gov ID: NCT06358027.

Keywords: Lung ultrasonography, Atelectasis, Postoperative pulmonary complications, Pressure support ventilation, Lung ultrasound score. (JPMA 76: 646; 2026) **DOI: https://doi.org/10.47391/JPMA.22711**

Introduction

Postoperative pulmonary complications are frequently observed in patients undergoing non-cardiothoracic surgery, and are associated with poor clinical outcomes up to one year after surgery.[1] Postoperative pulmonary complications, which occur in up to 40% of patients, have a significant contribution to postoperative morbidity and mortality.[2] During emergence from anaesthesia, the residual effects of anaesthetic agents and neuromuscular blockers may reduce the respiratory drive, preventing the patients from regaining functional residual capacity.[3,4] Pressure support ventilation (PSV) is preferred during the awakening phase in intensive care patients, and is now also used in anaesthesia machines employed in operating rooms (ORs).[5]

Lung transthoracic ultrasound (LUS) is a widely accessible and commonly used method for lung imaging that provides real-time dynamic imaging, avoiding the risks associated with ionising radiation. It is more accessible than specialised techniques, such as magnetic resonance imaging (MRI), and is characterised by high sensitivity and specificity.[6,7] Studies have shown that lung ultrasonography (USG) is highly correlated with thoracic computed tomography (CT) for determining the presence and size of atelectasis.[8]

The current study was planned to investigate the effects of different ventilatory approaches during the recovery phase of anaesthesia on the incidence of atelectasis in adult patients undergoing nonspecific surgeries. The null hypothesis was that the frequency of atelectasis would be lower in patients receiving PSV.

Department of Anaesthesiology and Reanimation, Dokuz Eylul University Research and Application Hospital, Izmir, Turkiye.

Correspondence: Busra Otlu Biyikoglu. e-mail: busraotlu08@gmail.com
ORCID ID: 0000-0002-0664-2560

Submission complete: 11-12-2024 **1st Revision received:** 15-04-2025
Acceptance: 27-12-2025 **Last Revision received:** 26-12-2025

Patients and Methods

The prospective cohort study was conducted from August to November 2022 at Dokuz Eylul University Hospital, Izmir, Turkiye, and was registered with ClinicalTrials.gov (ID: NCT06358027).

After approval from the institutional ethics review committee, the sample was raised using convenience sampling technique. Those included were patients aged at least 18 years with an American Society of Anaesthesiologists (ASA)[9] physical status classification of I-III who had undergone elective ophthalmic surgery, extremity surgeries, or septorhinoplasty procedures under general anaesthesia (GA) with endotracheal intubation for a duration of 1-3 hours. Those who were pregnant, had upper respiratory tract infection within the preceding 3 weeks, and had a history of difficult intubation and/or difficult ventilation were excluded. Also excluded were those with a history of lung surgery, laparoscopic and open abdominal and gynaecological surgeries, urological robotic surgeries, advanced cardiac disease, advanced pulmonary disease, chest wall deformity and patients who refused to volunteer. Informed consent was obtained from all the participants. Routine preoperative anaesthesia evaluations and physical examinations were done by resident physicians in the anaesthesiology outpatient clinic who also collected laboratory data. Preoperative pulmonary evaluation included medical history, while physical examination comprised bilateral lung auscultation, pulse oximetry (SpO_2) and posteroanterior chest radiography (CXR).

The Charlson Comorbidity Index (CCI) was calculated for all patients at the time of enrolment using the MedCalc online calculator.[10] The CCI is a validated prognostic tool that weighs 19 comorbid conditions, including cardiovascular, pulmonary, renal, hepatic and malignant diseases, to predict long-term mortality, with higher scores indicating greater comorbidity burden.

The patients were divided into PSV group A and manual ventilation group B. Since manual ventilation is the routine institutional practice, group B served as the reference group.

Age, gender, weight, height, comorbidities, and smoking history of the patients were recorded. None of the patients received preoperative sedative medication. Standard monitoring techniques were applied to all patients according to ASA[9] recommendations. A peripheral vascular access was established with an 18G or 20G cannula. Anaesthesia induction consisted of 2-3mg/kg propofol and 1-2mcg/kg fentanyl along with 0.6mg/kg rocuronium to assist with intubation. Maintenance was sustained with 0.1-0.4mcg/kg/min remifentanil, 2% sevoflurane and a 50% oxygen/air mix. Pain relief was provided with 1mg/kg tramadol, 1g paracetamol and 20mg tenoxicam.

Mechanical ventilation was performed in volume-controlled mode using a Dräger Atlan A350/A350 XL anaesthesia machine (Drägerwerk AG & Co. KGaA, Lübeck, Germany). The ventilation settings comprised a tidal volume of 6-8 mL/kg, a rate of 10-12 breaths/min, inspiration expiration ratio (I:E) ratio 1:2, flow 40-60L/min, positive end expiratory pressure (PEEP) 5. Upon completion of the surgery, the muscle relaxant effects were antagonised using sugammadex 2-4mg/kg.

The time to awaken from anaesthesia and the time from last surgical suture to extubation were recorded for both the groups. Upon readiness for extubation, the patients were either transitioned to PSV or manual ventilation at the discretion of the anaesthesiologist.

Patients had lung ultrasound imaging preoperatively right before entering the OR, and postoperatively 30 minutes after the surgery. The patients were imaged using a 3.5-5MHz convex probe with a portable ultrasound system (LOGIQ-E, GE HealthCare, United States). LUS imaging was done by the same anaesthesiologist both preoperatively and postoperatively, and he was blinded to the patient groups. The lungs were partitioned into 12 regions (6 regions in each lung: anterior, lateral and posterior, each with superior and inferior areas). The probe was placed perpendicularly in the anterior and lateral regions, and transversely in the posterior regions near the diaphragm. Imaging was performed for about 10-15 minutes following the standard protocol.

The modified LUS scoring system[11] was used to work out atelectasis scores for each region. Each area was scored 0-3 on the basis of atelectasis severity. Score 0 indicated no atelectasis, score 1 indicated mild atelectasis, score 2 indicated moderate atelectasis, and score 3 represented the highest degree of atelectasis, indicating significant areas of the lungs affected by atelectasis. The total score ranged from 0= normal to 36=absence of ventilation.

Respiratory complications were assessed postoperatively using SpO_2 monitoring at 0 and 30 minutes, oxygen requirement (supplemental oxygen needed to maintain $SpO2 \geq 94\%$), respiratory rate, dyspnoea assessment, and lung auscultation. These parameters were documented by recovery room staff blinded to the patient groups.

Jeong H. et al.[12] reported that the frequency of atelectasis by ultrasound in the recovery unit was 57% in patients who underwent laparoscopic cholecsytomy or robotic prostatectomy and were ventilated with intermittent manual assisted spontaneous breathing in the pre-extubation period. Based on this study[12] the current sample was raised using convenience sampling rather than a predetermined formal priori power calculation. Post-hoc power analysis was conducted using observed proportions of the primary outcome (postoperative atelectasis presence, defined as LUS score ≥1). For the purpose of sample size calculation, the observed incidences were obtained from previously published studies in comparable populations.[12] Using these incidences 60.4% in the PSV group and 76.3% in the manual ventilation group (absolute difference 15.9%, p=0.005), a two-proportion z-test (G*Power 3.1.9.4) revealed 81.2% power (effect size h=0.35, α=0.05, two-tailed), confirming adequate statistical power to detect clinically meaningful differences.[13]

Data was analysed using SPSS 25. Continuous variables were expressed as mean±standard deviation or median with interquartile range (IQR) depending on their distribution, while categorical variables were expressed as frequencies and percentages. Data normality was assessed using the Kolmogorov-Smirnov test. For comparisons between the groups, student's t-test was used for normally distributed continuous variables, and Mann-Whitney U test for non-normality distributed variables. Categorical variables were compared using Pearson's chi-square test. The relationship between COPD presence and atelectasis score was analysed using the Mann-Whitney U test. Correlation of atelectasis score with age, ASA score, CCI and COPD presence (coded as a binary variable) was evaluated using Spearman's rho correlation analysis. P<0.05 was considered statistically significant.

Results

Of the 2878 patients, 139(50%) were in group A; 72(51.8%) males and 67(48.2%) females with overall mean age 45.4±19.1 years. The remaining 139(50%) were in group B; 71(51.1%) males and 68(48.9%) females with overall mean age 49.7±18.6 years (p>0.05). Duration of surgery and time to recovery were not significantly different between the groups (Table 1).

The postoperative LUS scores for both the right and left lungs were significantly different (p<0.05). The total LUS median values were 1 (IQR: 0-3) in group A and 2(IQR: 0-4) in group B (p=0.041). Atelectasis was present in 106(76%) patients in group B compared to 84(60%) in group A (p=0.005) (Table 2).

Postoperative atelectasis scores had significant correlation with age, COPD, CCI and ASA) score (Table 3).

Among patients with COPD, the total postoperative LUS score was significantly higher than among patients without COPD (p=0.004) (Table 4).

The highest postoperative LUS scores for each lung region of the patients were noted (Figure).

In group A, 55(39.6%) patients showed no atelectasis, 63(45.3%) had a score of 1, and 21(15.1%) had a score of 2. No patient in group A had a score of 3.

In group B, 34(24.5%) patients had no atelectasis, 85(61.2%) had a score of 1, 18(12.9%) had a score of 2, and 2(1.4%) had a score of 3.

Table-1: Demographic characteristics.

	Group PSV n (%)	Group Manual n (%)	*p*-value
Gender			
Female†	72(51.8)	71(51.1)	0.904
Male†	67(48.2)	68(48.9)	
Mean Age (years)‡	45.4±19.1	49.7±18.6	0.060
Mean Weight (kg)‡	72.4±13.4	72.5±12.6	0.985
Mean Height (cm) ‡	1.6±0.09	1.7±0.08	0.761
Mean BMI (kg/m2) ‡	25.1±3.7	25±3.9	0.921
ASAI†	39(28.1)	31(22.3)	0.540
ASAII†	97(69.8)	105(75.5)	0.540
ASAIII†	3(2.2)	3(2.2)	0.540
CCI Median (IQR) ‡	0 (0-3)	1 (0-3)	0.132
Non-Smoking n%†	96(69.6)	92(66.2)	0.547
Smoking n%†	42(30.4)	47(33.8)	
Duration of surgery(minutes) Median (IQR) ‡	140(90-180)	110 (60-150)	0.085
Duration of emergence(minutes) Median (IQR) ‡	11(8-15)	10 (8-15)	0.247

PSV: Pressure support ventilation, ASA: American Society of Anaesthesiologist, CCI: Charlson Comorbidity Index, BMI: Body mass index, SD: Standard deviation, IQR: Interquartile range.
†Pearson chi-square test; ‡Student t-test

Table-2: Intergroup comparison of postoperative lung ultrasound and atelectasis scores.

	Group PSV	Group Manual	*p*-value
Right Lung Total Median (IQR)	0(0-2)	1(0-2)	0.02*
Left Lung Total Median (IQR)	0(0-2)	1(0-2)	0.05*
Total Atelectasis Score Median (IQR)	1(0-3)	2(1-4)	0.041*
Total atelectasis n(%)	84 (60.4)	106 (76.3)	0.006*

IQR: Interquartile range. * p<0.005

Table-3: Correlation of postoperative atelectasis score with age, chronic obstructive pulmonary disease (COPD), Charlson Comorbidity Index (CCI) and American Society of Anaesthesiologists (ASA) score.

Variable	Correlation Coefficient (r)	*p*-value
Age	0.254	<0.001
COPD	0.308	<0.001
CCI	0.288	<0.001
ASA score	0.199	0.001

Table-4: Comparison of postoperative lung transthoracic ultrasound (LUS) score between patients with and without chronic obstructive pulmonary disease (COPD).

COPD Status(n)	Postoperative Total LUS Score	*p*-value
Present (6)	Median 8 (IQR: 4.5-14)	0.004*
Absent (272)	Median 1 (IQR: 0-4)	

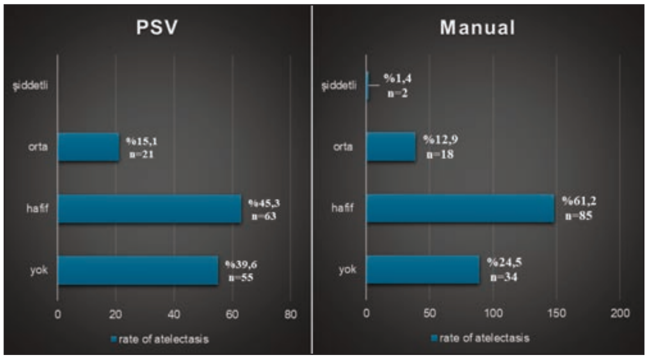

Figure: Distribution of the highest atelectasis scores of the cases between pressure support ventilation (PSV) and manual ventilation groups.

Discussion

The current study evaluated the presence of ventilation deficiencies and atelectasis in the lungs using LUS in the postoperative recovery unit for patients who underwent planned surgeries under GA. Modified LUS scores were reduced in patients extubated with PSV compared to those extubated with manual ventilation.

PSV is commonly employed in intensive care units (ICUs) to facilitate weaning from mechanical ventilation. The latest guidelines from the American Thoracic Society recommend PSV for successful weaning.[14] While PSV facilitates easier breathing when it is switched on after the discontinuation of inhalation anaesthetics, there are concerns about potential postoperative respiratory failure upon the discontinuation of support. Consequently, manual ventilation, which allows for monitoring of spontaneous breathing, is frequently used in clinical practice during extubation.[15,16]

The current findings demonstrated that PSV mode was not associated with increased respiratory complications. No significant associations were noted PSV with hypoxia (as measured by SpO_2 at 0 and 30 minutes), oxygen requirements, or clinical signs of respiratory distress (tachypnoea, dyspnoea, abnormal lung sounds). Conversely, PSV was associated with a reduced incidence of atelectasis. These findings align with the American Thoracic Society's recommendations for PSV.

One mechanism by which PSV may reduce postoperative atelectasis is by decreasing the work of breathing during inspiration. PSV can reduce this work by up to 40% through the application of inspiratory pressure support, thus assisting in lung ventilation.[17] Additionally, maintaining a PEEP of 5cm water (H_2O) until the end of extubation can help prevent airway closure, particularly in dependent lung regions, thereby reducing or preventing atelectasis.[18]

Previous studies[11,19,20] using CT or lung ultrasound have shown that atelectasis frequently develops in the posterior and basal regions of the lungs, which is consistent with the current findings. Jeong et al.[12] conducted a randomised controlled double-blind study comparing manual support and pressure support modes during awakening from anaesthesia in 100 patients who underwent laparoscopic colectomy and robot-assisted laparoscopic prostatectomy. They reported a lower incidence of postoperative atelectasis in patients who received PSV than in those who were manually ventilated. In their study, the average postoperative modified LUS scores were 3(IQR: 1-6) for the manual ventilation group and 5(IQR: 2-8) for the PSV group (p=0.024). The current study also revealed significantly lower postoperative atelectasis scores (p=0.005) in the PSV group than in the manual ventilation group (Table 3). The lower scores in the current study compared to previous literature may be attributed to the peripheral nature of the surgeries in the current cohort, such as extremity and ear-nose-throat (ENT) surgeries, which typically have less impact on respiratory mechanics, and a lower average patient age.

High-risk surgical operations, longer surgery durations, and the type and duration of anaesthesia can increase the risk of postoperative atelectasis and pulmonary complications. Clinical general thoracic and major abdominal surgeries are particularly associated with an increased risk of atelectasis.[21,22] Postoperative pulmonary complications have an incidence ranging 5-33% and are the second most common cause of postoperative 30-day mortality, following surgical site infections.[20] Atelectasis, regardless of surgery type or anaesthesia method, can lead to postoperative pulmonary complications.[23] A study comprising patients undergoing minimally invasive oesophagectomy demonstrated that the use of volatile anaesthesia, compared to propofol-based intravenous anaesthesia, reduced the risk of atelectasis within the first 7 postoperative days.[24]

While most atelectasis in the early postoperative period is self-limiting, severe cases can lead to complications, such as low oxygen saturation, consolidation, pleural effusion, respiratory failure and pneumonia, potentially resulting in prolonged mechanical ventilation and hospital stay.[25]

Xie et al.[26] evaluated 80 patients who underwent single-lung ventilation during thoracic surgery, and used LUS to monitor ventilation loss before induction, 5 minutes post-intubation, at the end of surgery, and 15 minutes after extubation. They reported a significant increase in LUS scores from 0.15±0.58 before induction to 5.64±2.72 after extubation (p<0.001). These finding highlight the importance of LUS as a non-invasive method for diagnosing pleural effusion and pneumothorax.

The higher atelectasis scores in Xie et al.'s study[26] are likely due to the complex thoracic surgeries performed, which included lobectomy, segmentectomy and mediastinal tumour excision. The current study excluded patients with severe respiratory failure or significant lung masses. However, the current study observed significantly higher LUS scores in patients with mild to moderate COPD (8.33±5.27, p=0.004) (Table 4). In future studies, comparing different surgical techniques and patient groups may be important for better understanding the risk of postoperative atelectasis.

The current study has limitations. The primary limitation is that LUS is a practitioner-dependent technique that requires patient cooperation. While LUS scores provide valuable information on the incidence of atelectasis, the findings were not corroborated by lung CT, which remains the gold standard for diagnosing atelectasis. Additionally, the study assessed patients only in the early postoperative period in the recovery room. It did not assess the impact of LUS scores on postoperative outcomes or their clinical implications for patients. Another limitation of the study is that the sample size was not based on a priori power calculation specifically designed for the non-abdominal surgical population. However, post-hoc analysis demonstrated adequate statistical power (81.2%) to detect clinically significant differences in the primary outcome.

Conclusion

There were significant differences between patient groups receiving PSV and those receiving manual ventilation while awakening from anaesthesia, with results favouring PSV in terms of modified LUS scores.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

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Author Contribution:

BOB: Concept, design, data acquisition, analysis, drafting, revision, final approval and agreement to be accountable for all aspects of the work.

BSY: Study design, data analysis, drafting, critical revision, final approval and agreement to be accountable for all aspects of the work.

VH: Literature review, data interpretation, statistical analysis, final approval and agreement to be accountable for all aspects of the work.

ASB: Data collection, analysis, drafting, revision, final approval and agreement to be accountable for all aspects of the work.