International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Preoperative Lung Ultrasound Findings and Their Association with Intraoperative Oxygenation in Patients Undergoing Major Surgery: A Prospective Observational Study

Dr Vinod Kumar M[1], Dr Charulatha[2], Dr Shynee J N[3]

[1]*Senior Resident, Department of Radiodiagnosis, Navodaya Medical College, Raichur, Karnataka, India*
[2]*Assistant Professor, Department of Anaesthesiology, Navodaya Medical College, Raichur, Karnataka, India*
[3]*Consultant Anaesthesiologist, Government General Hospital, Anekal , Bangalore, Karnataka, India*

OPEN ACCESS

Corresponding Author:

Dr Charulatha
Assistant Professor, Department of Anaesthesiology, Navodaya Medical College, Raichur, Karnataka, India

Received: 20-07-2025
Accepted: 15-08-2025
Available online: 25-08-2025

ABSTRACT

Background: General anesthesia and positive-pressure ventilation frequently reduce lung aeration, predisposing patients to intraoperative oxygenation decline. Bedside lung ultrasound can detect interstitial patterns, atelectasis, and small effusions before induction.

Objectives: To describe preoperative lung ultrasound (LUS) findings in adults undergoing major surgery and determine their association with early intraoperative oxygenation.

Methods: In this prospective observational study, adults scheduled for major elective surgery underwent standardized preoperative LUS. Abnormal LUS patterns included predominant B-lines, pleural line irregularity, basal atelectasis patterns, subpleural consolidations, or pleural effusion. Intraoperative oxygenation was assessed using the worst PaO_2/FiO_2 within the first 120 minutes after induction and the occurrence of hypoxemia (SpO_2 <92% for ≥1 minute). Multivariable regression evaluated independent associations after adjustment for age, BMI, ASA class, smoking, COPD/asthma, and surgery duration.

Results: Among 100 analyzed patients, abnormal preoperative LUS was present in 58%. The median lowest intraoperative PaO_2/FiO_2 was 292 (IQR 248–336), and hypoxemia occurred in 26%. Patients with abnormal LUS had lower PaO_2/FiO_2 (median 270 vs 324) and higher rates of PaO_2/FiO_2 <200 and hypoxemia. In adjusted models, abnormal LUS remained associated with PaO_2/FiO_2 <200 and a lower lowest PaO_2/FiO_2.

Conclusion: Preoperative LUS abnormalities were common and independently associated with impaired early intraoperative oxygenation. Incorporating pre-induction LUS could help risk-stratify patients and prompt targeted ventilatory optimization.

***Keywords**: Lung ultrasound; Preoperative assessment; Atelectasis; Hypoxemia; PaO_2/FiO_2 ratio; Major surgery; Mechanical ventilation.*

INTRODUCTION

Impaired oxygenation during major surgery remains a frequent intraoperative challenge, even in patients with acceptable baseline respiratory status. General anesthesia reduces functional residual capacity, promotes dependent airway closure, and can rapidly generate absorption and compression atelectasis, particularly in basal lung regions [1-3]. The resulting shunt fraction and ventilation–perfusion mismatch contribute to a fall in arterial oxygenation and, in susceptible patients, clinically relevant desaturation episodes. In upper abdominal procedures, intraoperative oxygenation indices have been linked to postoperative hypoxemia and pulmonary morbidity, highlighting the clinical value of early oxygenation signals during anesthesia [4].

Traditional bedside tools used by anesthesiologists to interpret oxygenation decline such as auscultation, airway pressure trends, and capnography provide indirect or non-specific information. Imaging is often delayed or impractical in the operating room. Computed tomography can quantify atelectasis with high fidelity, but it is not feasible in routine intraoperative care. Lung ultrasound (LUS) has emerged as an accessible, radiation-free modality with good diagnostic performance for pleural effusion, consolidation, and interstitial syndromes, and it can be applied repeatedly at the bedside [5,6]. In addition, it can be integrated into routine preoperative assessment without patient transport. Recent international guidance has emphasized standardized reporting of scanning regions, probe selection, and interpretive criteria to improve reproducibility across settings [6].

For perioperative practice, LUS offers two practical advantages. First, it can identify pre-existing aeration loss, small posterior consolidations, or effusions that are not clinically evident before induction. Second, it supports a physiologically grounded response to oxygenation decline by clarifying whether the predominant pattern is atelectasis, interstitial change, or effusion. Semi-quantitative scoring systems, including modified approaches designed to improve pleural visualization, permit severity grading and facilitate correlation with clinically meaningful endpoints [7,8]. In parallel, perioperative feasibility work and expert perspectives suggest that LUS can function as an early, bedside adjunct when evaluating intraoperative hypoxemia and monitoring response to recruitment maneuvers and PEEP adjustment [9,10].

Despite expanding interest, local evidence linking pre-induction LUS patterns to early intraoperative oxygenation trajectories in major surgery remains limited, particularly in mixed surgical cohorts typical of tertiary-care practice. Establishing such an association can justify preoperative LUS as a simple risk stratification step and inform proactive ventilatory optimization.

OBJECTIVES

(1) To determine the frequency and distribution of preoperative LUS abnormalities in adults undergoing major elective surgery; (2) To evaluate the association between abnormal preoperative LUS and early intraoperative oxygenation, including worst PaO_2/FiO_2 within 120 minutes and hypoxemia events; and (3) To identify independent predictors of impaired oxygenation after adjustment for relevant clinical covariates.

MATERIALS AND METHODS

Study design and setting: This prospective observational study was conducted at Navodaya Medical College and Research Centre, Raichur, Karnataka, India, from November 2024 to April 2025. Institutional Ethics Committee approval was obtained before recruitment, and written informed consent was taken from all participants.

Participants: Adults scheduled for major elective surgery under general anesthesia were screened. Major surgery was defined as procedures expected to last ≥90 minutes with planned tracheal intubation and controlled ventilation. Exclusion criteria were recent pneumothorax or pleural intervention, severe hemodynamic instability, refusal of consent, and anticipated one-lung ventilation. Participants were withdrawn if an unexpected one-lung ventilation strategy occurred. The planned sample size was 100 analyzed patients.

Preoperative lung ultrasound protocol: LUS was performed within 2 hours before induction by a trained anesthesiologist. Scanning covered anterior, lateral, and posterior/basal regions using standard point-of-care principles [5,6]. Lung zones were assessed for A-lines, B-lines, pleural line irregularity, subpleural consolidations, basal atelectasis patterns, and pleural effusion. Predominant B-lines were defined as ≥2 zones with ≥3 B-lines. Abnormal LUS was defined as any abnormal pattern. Aeration loss was summarized using a semi-quantitative score adapted from validated LUS scoring (0–3 per zone) with standardized descriptors for pleural and B-line abnormalities [7,8]. Severity was categorized into mild/none, moderate, and severe groups for analysis.

Anesthesia, ventilation, and rescue strategy: General anesthesia was provided according to institutional practice. Ventilation followed a protective strategy with tidal volume 6–8 mL/kg predicted body weight and initial PEEP of 5 cmH_2O. FiO_2 was titrated to maintain SpO_2 ≥94% while avoiding unnecessarily high FiO_2 where feasible, given its link to atelectasis development [2,3]. Rescue measures for oxygenation decline included recruitment maneuver, PEEP escalation, bronchodilator therapy, suctioning, or temporary FiO_2 increase.

Oxygenation measurements and outcomes: The primary oxygenation metric was the worst PaO_2/FiO_2 recorded within the first 120 minutes after induction. Hypoxemia was defined as SpO_2 <92% sustained for ≥1 minute. PaO_2/FiO_2 <200 was used as a categorical indicator of clinically significant impairment. Secondary outcomes included rescue interventions and lowest intraoperative SpO_2.

Statistical analysis: Data are presented as mean ± SD, median (IQR), or n (%). Comparisons used Mann–Whitney U test and χ^2/Fisher's exact tests. Multivariable logistic regression modeled PaO_2/FiO_2 <200, and linear regression modeled lowest PaO_2/FiO_2, adjusting for age, BMI, ASA class, smoking, COPD/asthma, and surgery duration. All analyses were performed in SPSS (version 26.0). Continuous variables were checked for normality using the Shapiro–Wilk test; no imputation was required. A p value <0.05 was considered significant.

RESULTS

Participant flow and completeness: During the study period, 112 patients were screened. Ten did not meet eligibility criteria (recent pneumothorax/pleural intervention: 3; severe hemodynamic instability: 2; refusal of consent: 5). Two were excluded after enrollment due to intraoperative protocol deviation (unexpected one-lung ventilation). Finally, 100 patients were analyzed with complete preoperative lung ultrasound (LUS) and intraoperative oxygenation data.

Baseline characteristics: The cohort had a mean age of 54.7 ± 12.8 years and 62% were male. Most patients were overweight or obese and nearly one-third were ASA class III. Baseline room-air oxygen saturation was high, consistent with an elective major-surgery population (Table 1).

Table 1. Baseline demographic and clinical profile (N = 100)

Variable	Value
Age (years), mean ± SD	54.7 ± 12.8
Age group (years), n (%)	18–39: 18 (18.0); 40–59: 46 (46.0); ≥60: 36 (36.0)
Sex, n (%)	Male: 62 (62.0); Female: 38 (38.0)
BMI (kg/m²), mean ± SD	26.1 ± 4.3
BMI category, n (%)	<25: 40 (40.0); 25–29.9: 42 (42.0); ≥30: 18 (18.0)
ASA physical status, n (%)	I: 16 (16.0); II: 54 (54.0); III: 30 (30.0)
Smoking status, n (%)	Current: 22 (22.0); Former: 18 (18.0); Never: 60 (60.0)
Known COPD/asthma, n (%)	16 (16.0)
Baseline SpO_2 on room air (%), mean ± SD	97.1 ± 1.4
Planned surgery duration (min), mean ± SD	176 ± 58

Preoperative lung ultrasound findings: Abnormal preoperative LUS findings were observed in 58% of patients. The most frequent patterns were predominant B-lines and pleural line irregularity, followed by small subpleural consolidations and basal atelectasis patterns, suggesting reduced aeration in posterior/basal regions before anesthesia (Table 2).

Table 2. Preoperative LUS patterns (N = 100)

LUS finding	n (%)
Any abnormal LUS finding	58 (58.0)
Predominant B-lines (≥2 zones with ≥3 B-lines)	36 (36.0)
Small subpleural consolidation(s)	18 (18.0)
Pleural line irregularity	22 (22.0)
Basal atelectasis pattern (posterior consolidation/hepatization without air bronchograms)	14 (14.0)
Pleural effusion (small/moderate)	12 (12.0)
Normal aeration pattern	42 (42.0)

Intraoperative oxygenation outcomes: The median worst PaO_2/FiO_2 ratio within the first 120 minutes after induction was 292 (IQR 248–336). Hypoxemia events requiring escalation of oxygenation strategy occurred in 26% of cases, most commonly managed with recruitment maneuvers and/or PEEP adjustment. Detailed oxygenation and ventilation outcomes are shown in Table 3.

Table 3. Intraoperative oxygenation and ventilation outcomes (N = 100)

Outcome	Value
Lowest PaO_2/FiO_2 in first 120 min, median (IQR)	292 (248–336)
Lowest SpO_2 intraoperatively (%), mean ± SD	94.8 ± 2.9
PaO_2/FiO_2 category, n (%)	≥300: 48 (48.0); 200–299: 38 (38.0); <200: 14 (14.0)
Any hypoxemia episode (SpO_2 <92% ≥1 min), n (%)	26 (26.0)
Rescue intervention needed*, n (%)	24 (24.0)
Recruitment maneuver performed, n (%)	20 (20.0)
PEEP escalation ≥2 cmH_2O, n (%)	22 (22.0)

*Rescue intervention = any of: recruitment maneuver, PEEP escalation, bronchodilator, suctioning for suspected secretion load, or temporary increase in FiO_2 above the protocol target.

Association between preoperative LUS and intraoperative oxygenation: Patients with abnormal preoperative LUS had significantly lower worst PaO_2/FiO_2 and more frequent hypoxemia episodes compared with those with normal LUS (Table 4).

Table 4. Oxygenation outcomes by preoperative LUS status

Parameter	Abnormal LUS (n = 58)	Normal LUS (n = 42)	p value

Lowest PaO_2/FiO_2, median (IQR)	270 (232–312)	324 (292–360)	<0.001
PaO_2/FiO_2 <200, n (%)	12 (20.7)	2 (4.8)	0.02
Any hypoxemia (SpO_2 <92%), n (%)	20 (34.5)	6 (14.3)	0.02
Rescue intervention needed, n (%)	18 (31.0)	6 (14.3)	0.04

A graded relationship was observed when aeration loss severity was considered. The severe LUS group had the lowest PaO_2/FiO_2 values and the highest proportion of PaO_2/FiO_2 <200 (Table 5).

Table 5. Oxygenation by LUS aeration loss severity (3-tier grouping)

LUS severity group	n	Lowest PaO_2/FiO_2, median (IQR)	PaO_2/FiO_2 <200, n (%)
Mild/none	50	318 (284–352)	3 (6.0)
Moderate	32	282 (244–316)	5 (15.6)
Severe	18	236 (198–276)	6 (33.3)

Predictors of impaired intraoperative oxygenation: On multivariable analysis, abnormal preoperative LUS remained independently associated with PaO_2/FiO_2 <200 after adjustment for age, BMI, ASA class, smoking, COPD/asthma, and surgery duration. In linear regression, abnormal preoperative LUS and higher BMI were associated with a lower worst PaO_2/FiO_2 (Table 6).

Table 6A. Multivariable logistic regression for PaO_2/FiO_2 <200

Predictor	Adjusted OR (95% CI)	p value
Abnormal preoperative LUS	4.6 (1.2–17.3)	0.02
BMI (per 1 kg/m²)	1.08 (1.00–1.17)	0.04
COPD/asthma	2.1 (0.6–7.7)	0.26
Age (per 10 years)	1.3 (0.9–1.9)	0.12

Table 6B. Multivariable linear regression for lowest PaO_2/FiO_2

Predictor	β coefficient (95% CI)	p value
Abnormal preoperative LUS	−44 mmHg (−66 to −22)	<0.001
BMI (per 1 kg/m²)	−3.2 mmHg (−5.6 to −0.8)	0.01
Longer surgery duration (per 60 min)	−9 mmHg (−18 to 0)	0.05

Clinically relevant secondary observations: Posterior/basal abnormalities (dependent B-lines or atelectasis patterns) showed the strongest link to oxygenation decline, with PaO_2/FiO_2 <200 occurring in 10/44 (22.7%) with dependent patterns versus 4/56 (7.1%) without dependent patterns. Pleural effusion (small/moderate) was associated with a higher need for rescue intervention (6/12, 50.0%) compared with those without effusion (18/88, 20.5%). No ultrasound-related adverse events occurred.

DISCUSSION

In this prospective cohort of adults undergoing major surgery, preoperative lung ultrasound abnormalities were frequent and carried clinically relevant information about early intraoperative oxygenation. More than half of the participants demonstrated reduced aeration features most commonly dependent B-lines and small subpleural consolidations suggesting that a proportion of elective surgical patients enter the operating room with occult regional aeration loss. This observation is consistent with the perioperative tendency toward dependent airway closure and atelectasis after induction and muscle paralysis [1-3].

Patients with abnormal preoperative LUS had a lower worst PaO_2/FiO_2 within 120 minutes and a higher incidence of desaturation events, with a clear gradient across LUS severity strata. These results align with perioperative feasibility studies showing that LUS can detect aeration changes associated with perioperative atelectasis and oxygenation shifts [9]. They also support expert views that LUS is a practical first-line adjunct when intraoperative hypoxemia occurs because it enables rapid pattern-based differentiation and serial monitoring during recruitment and PEEP titration [10].

Posterior and basal abnormalities showed the strongest association with PaO_2/FiO_2 <200, a relationship that is physiologically plausible because dependent regions are most susceptible to collapse and shunt during anesthesia. Similar links between ultrasound-detected atelectasis and perioperative oxygenation have been described in recovery-unit settings, reinforcing the clinical coherence of LUS-based aeration metrics across the perioperative continuum [11]. In the adjusted models, abnormal preoperative LUS and higher BMI were associated with worse oxygenation, consistent with reduced compliance and an increased propensity for dependent collapse in overweight patients [1,2].

Beyond intraoperative oxygenation, perioperative LUS has been evaluated for early detection of postoperative pulmonary complications after major abdominal surgery. A prospective feasibility study demonstrated that routine LUS screening can identify postoperative pulmonary complications and support timely clinical escalation, strengthening the role of LUS as a bridge between intraoperative physiology and downstream recovery risk [12]. In that context, our pre-induction findings offer an upstream signal that could be integrated with postoperative surveillance to create a continuous, aeration-focused monitoring pathway.

Implementation requires standardization. International recommendations and newer consensus guidance emphasize consistent scanning regions and explicit interpretive criteria [5,6]. Structured aeration scoring systems, including modified approaches that enhance pleural visualization, provide a pragmatic framework for severity grading and for tracking response to ventilatory adjustments [7,8]. Interventional studies have shown that ultrasound-guided recruitment strategies combined with PEEP optimization can reduce atelectasis and improve oxygenation in selected upper abdominal surgery populations [13], and perioperative treatment bundles guided by LUS have also been explored in complex surgical groups [14].

Taken together, these findings support the role of a brief pre-induction LUS screen as a practical risk stratification step. Larger studies should test whether LUS-guided preventive pathways reduce postoperative pulmonary complications and improve recovery outcomes.

Limitations

This single-center study included a heterogeneous surgical case-mix, limiting procedure-specific inference. Ultrasound interpretation is operator dependent, and inter-observer reliability was not quantified. Computed tomography confirmation of aeration loss was not performed. Oxygenation outcomes were limited to the first 120 minutes after induction. Key covariates such as fluid balance, positioning, and neuromuscular blockade depth were not modeled, leaving clinically important residual confounding.

CONCLUSION

Preoperative lung ultrasound abnormalities were present in 58% of adults scheduled for major elective surgery and were associated with clinically meaningful impairment in early intraoperative oxygenation. Patients with abnormal preoperative LUS exhibited lower worst PaO_2/FiO_2 values and higher frequencies of hypoxemia episodes and rescue ventilatory interventions. The association persisted after adjustment for age, BMI, ASA class, smoking status, COPD/asthma, and surgical duration, supporting abnormal LUS as an independent marker of oxygenation vulnerability. A brief, standardized pre-induction LUS assessment can serve as a practical bedside screening step to identify higher-risk patients and guide proactive, individualized ventilatory optimization during major surgery within routine perioperative workflows. Such early stratification can also support timely allocation of monitoring and respiratory resources.

REFERENCES

1. Hedenstierna G, Edmark L. Mechanisms of atelectasis in the perioperative period. Best Pract Res Clin Anaesthesiol. 2010;24(2):157-69. doi:10.1016/j.bpa.2009.12.002.
2. Hedenstierna G, Rothen HU. Atelectasis formation during anesthesia: causes and measures to prevent it. J Clin Monit Comput. 2000;16(5-6):329-35. doi: 10.1023/a:1011491231934. PMID: 12580216.
3. Hedenstierna G, Edmark L. The effects of anesthesia and muscle paralysis on the respiratory system. Intensive Care Med. 2005 Oct;31(10):1327-35. doi: 10.1007/s00134-005-2761-7. Epub 2005 Aug 16. PMID: 16132894.
4. Wetterslev J, Hansen EG, Kamp-Jensen M, Roikjaer O, Kanstrup IL. PaO2 during anaesthesia and years of smoking predict late postoperative hypoxaemia and complications after upper abdominal surgery in patients without preoperative cardiopulmonary dysfunction. Acta Anaesthesiol Scand. 2000 Jan;44(1):9-16. doi: 10.1034/j.1399-6576.2000.440103.x. PMID: 10669265.
5. Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW, et al. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med. 2012;38(4):577-91. doi:10.1007/s00134-012-2513-4.
6. 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 Feb;42(2):309-344. doi: 10.1002/jum.16088. Epub 2022 Aug 22. PMID: 35993596; PMCID: PMC10086956.
7. Mongodi S, Bouhemad B, Orlando A, Stella A, Tavazzi G, Via G, Iotti GA, et al. Modified Lung Ultrasound Score for Assessing and Monitoring Pulmonary Aeration. Ultraschall Med. 2017 Oct;38(5):530-537. English. doi: 10.1055/s-0042-120260. Epub 2017 Mar 14. PMID: 28291991.
8. 8.Fischer EA, Minami T, Ma IWY, Yasukawa K. Lung Ultrasound for Pleural Line Abnormalities, Confluent B-Lines, and Consolidation: Expert Reproducibility and a Method of Standardization. J Ultrasound Med. 2022 Aug;41(8):2097-2107. doi: 10.1002/jum.15894. Epub 2021 Nov 29. PMID: 34845735.
9. Monastesse A, Girard F, Massicotte N, Chartrand-Lefebvre C, Girard M. Lung Ultrasonography for the Assessment of Perioperative Atelectasis: A Pilot Feasibility Study. Anesth Analg. 2017 Feb;124(2):494-504. doi: 10.1213/ANE.0000000000001603. PMID: 27669555.

10. Díaz-Gómez JL, Renew JR, Ratzlaff RA, Ramakrishna H, Via G, Torp K. Can Lung Ultrasound Be the First-Line Tool for Evaluation of Intraoperative Hypoxemia? Anesth Analg. 2018 May;126(5):1769-1773. doi: 10.1213/ANE.0000000000002578. PMID: 29099431.
11. Wu L, Yang Y, Yin Y, Yang L, Sun X, Zhang J. Lung ultrasound for evaluating perioperative atelectasis and aeration in the post-anesthesia care unit. J Clin Monit Comput. 2023;37(5):1295-1302. doi:10.1007/s10877-023-00994-7.
12. Touw HR, Schuitemaker AE, Daams F, van der Peet DL, Bronkhorst EM, Schober P, Boer C, Tuinman PR. Routine lung ultrasound to detect postoperative pulmonary complications following major abdominal surgery: a prospective observational feasibility study. Ultrasound J. 2019 Sep 16;11(1):20. doi: 10.1186/s13089-019-0135-6. PMID: 31523784; PMCID: PMC6745303.
13. 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 Jan 30;9(2):e13348. doi: 10.1016/j.heliyon.2023.e13348. PMID: 36755592; PMCID: PMC9900369.
14. Goel N, Sen IM, Bakshi J. Lung ultrasonography as a tool to guide perioperative atelectasis treatment bundle in head and neck cancer patients undergoing free flap reconstructive surgeries: a preliminary observational study. Braz J Otorhinolaryngol. 2022 Mar-Apr;88(2):204-211. doi: 10.1016/j.bjorl.2020.05.030. Epub 2020 Jul 29. PMID: 32800584; PMCID: PMC9422385.