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*Original Article*

# Modified Lung Ultrasound Score to Determine the Degree of Perioperative Atelectasis in Adults Undergoing Elective Laparoscopic Surgery under General Anaesthesia- A Prospective Observational Study

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**ABSTRACT**

**Background:** Lung ultrasound score (LUS) is a semiquantitative assessment tool that has been proposed to assess lung aeration changes in mechanically ventilated patients after therapeutic interventions. In anaesthetized patient, LUS not only detects intraoperative atelectasis, but it also correlates with perioperative oxygenation impairment. The aim of this study was to assess the incidence and degree of atelectasis in patients undergoing laparoscopic surgery using LUS score.

**Methods:** Total patients selected in our study were 60 aged between 18-60 years who underwent laparoscopic surgery under general anaesthesia. According to the lung ultrasound protocol, a total of 12 areas were divided and scanned in both hemithorax at four-time intervals preoperative period (T1), immediately after intubation (T2), before extubation (T3) and one hour after extubation (T4). The image was assessed by anaesthesiologist experienced in lung ultrasound based on modified lung ultrasound scoring system.

**Results:** LUS at all four-time intervals were compared. We observed an increase in total LUS score T3 and T4 time period compared with preoperative (T1). LUS scores at posterior quadrants 5 and 6 on either side also increased at T3 & T4 time period ($p<0.001$). The incidence of atelectasis was 6.6%, 6.6%, 78%, and 80% at T1, T2, T3, and T4, respectively. No change in hemodynamics and oxygen saturations were observed in all patients at various time periods.

**Conclusion:** This study concluded that incidence and degree of atelectasis was found to be higher in the dependent lung zones as demonstrated by lung ultrasound score in adults undergoing laparoscopic surgeries under general anesthesia.

**GRAPHICALABSTRACT**


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## Introduction

Bedside point of care ultrasonography is floridly used in emergency scenarios and critically ill patients for many years. The role of ultrasonography in pulmonary imaging has recently gained importance. A Lung ultrasound score (LUS) has been proposed to assess changes in lung aeration based on examination of 12 regions in the chest wall after therapeutic interventions in mechanically ventilated patients [1, 2]. LUS depending on the degree of aeration loss is graded between 0 and 3 in each segmental aeration of the examined area of lung [3, 4]. It is a semiquantitative assessment tool and the total score can vary between 0 and 36.

In anaesthetized patients, lung ultrasound not only detects intraoperative atelectasis, but also correlates with the perioperative oxygenation impairment. In addition, the capnoperitoneum created during laparoscopic surgery increases the abdominal pressure shifting the diaphragm cranially and further decreases respiratory compliance [5, 6]. Stiffened diaphragm compresses the basal lung regions which accelerate the atelectasis formation that was already initiated during anaesthesia induction. During laparoscopic gynaecologic or colonic surgeries steep trendlenberg position is used. It causes the abdominal contents to push the diaphragm more cephalad, resulting in aggravated lung collapse and decreased functional residual capacity [7, 8].

This intraoperative atelectasis is associated with decreased lung compliance, impaired oxygenation, increased pulmonary vascular resistance, and lung injury. Moreover, respiratory complications such as hypoxemia and infection may occur due to persistence of atelectasis postoperatively resulting in significant impairment of patient's recovery [9, 10].

This study aimed to assess the degree of atelectasis in patients undergoing elective laparoscopic surgery under general anesthesia using LUS score.

## Materials and Methods

This prospective observational study was conducted in Department of Anaesthesiology in a tertiary care center in Chennai, Tamilnadu, India. Sixty adults between the ages of 18 and 60 who were in ASA physical status I and II and scheduled for elective laparoscopic abdominal surgery under general anaesthesia were included after receiving approval from the institutional review board and the ethical committee. Patients who failed to provide written consent for study enrolment, those with BMI >35 kg/m$^2$, those with hepatic disease (serum liver enzyme values >50% of normal value), those with renal insufficiency (serum creatinine >1.8mg/dl), those who had undergone thoracic surgery in the past, those with severe chronic obstructive pulmonary disease, and those with diaphragmatic paralysis were excluded from the study. If saturation fell below 95%, the peak inspiratory pressure ($p_{peak}$) increases more than 35 mmhg as well as adverse events such as subcutaneous emphysema, pneumothorax, and pneumo-mediastinum were observed the study procedure was stopped.

All patients were enrolled in the study using simple random sampling. Blinding is not suitable for study. The patients were pre-medicated with Tablet Alprazolam 0.5 mg and tablet Pantoprazole the night before and on the day of surgery. On the day of surgery, patients were moved to the operating room where standard monitors were connected, and base line vitals were recorded. All the study participants underwent standardized general anesthesia induction and maintenance procedures.

Fentany l 2 mcg/kg and Propofol 2-2.5 mg/kg injections were used to induce general anesthesia after 3 minutes of preoxygenation with 100% oxygen. Tracheal intubation was facilitated with Injection Atracurium 0.5 mg/kg. Additional atracurium was administered as needed to maintain adequate muscle relaxation. Sevoflurane was used to maintain anesthesia with a target MAC of 1. Neostigmine 50 mcg/kg and glycopyrrolate 10 mcg/kg injections were used to reverse neuromuscular inhibition following surgery. For all patients, the mechanical ventilation was standardized. The ventilator was set in volume-controlled ventilation mode with tidal volume of 6-8 ml/kg of predicted body weight, $FiO_2$ of 0.50, respiratory frequency of 12 breaths/min adjusted to obtain end tidal carbon dioxide concentration between 30 and 35 mmhg, inspiratory to expiratory ratio of 1:2, PEEP (positive end expiratory pressure) of 5 mmhg and medical air were used instead of nitrous oxide.

Every five minutes during the procedure, as well as every 15 minutes for the first hour afterward in the recovery room, hemodynamics (HR and MAP), and oxygen saturations (SpO2) were measured.

GE Logic system with high frequency linear array probe (6-13 MHz) was used to perform lung ultrasonography at four different time points: T1 (before induction), T2 (after tracheal intubation), T3 (before extubation), and T4 (one hour after operation). Lung ultrasound was performed by two anaesthesiologists with experience of more than 100 cases in lung ultrasonography. According to the lung ultrasound protocol, both hemithorax (front, side, and back areas) were scanned for a total of 12 areas (six on each sided hemithorax), as shown in Figure 1A. These areas were divided into the upper and lower zones with two vertical lines drawn on the anterior axillary line and posterior axillary line, and one horizontal line drawn at mid mammary line across the nipples. The ultrasonic probe was positioned perpendicular to the ribs to produce the "bat sign view," and then it was rotated parallel to the ribs to obtain a larger lung view as displayed in Figure 1B. The image with the greatest loss of ventilation was captured after scanning each intercostal space in the area under investigation. The final lung ultrasound image, as depicted in Figure 1C, was obtained and used to evaluate any aeration loss.

Each area's score for the lack of ventilation was recorded, and each patient's overall score was calculated. According to the degree of atelectasis, each location was given a score between 0 and 3, as presented in Table 1. The overall score for the 12 areas ranged from 0 (no loss of aeration) to 36 (complete loss of aeration).

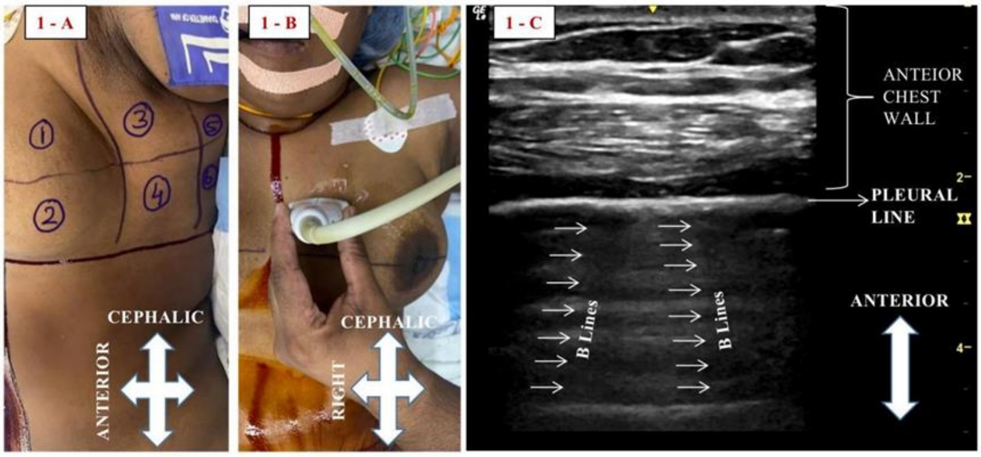


**Figure 1:** A) Six areas for scanning in patient's hemithorax, B) Final Ultrasound probe position, and C) Lung Ultrasound images obtained for LUS assessment (white arrows depicts the vertical B lines)

**Table 1:** Modified lung ultrasound scoring system [11]

| Score | Aeration | Findings |
|---|---|---|
| 0 | Normal aeration | 0-2 B lines |
| 1 | Small loss of aeration | B lines > 3 or 1 or more multiple subpleural consolidations separated by a normal pleural line |
| 2 | Moderate loss of aeration | Multiple coalescent B lines or multiple small subpleural consolidations separated by a thickened or irregular pleural line |
| 3 | Severe loss of aeration | Consolidation or small subpleural consolidations of > 1*2 cm in diameter |

The sample size was calculated using nMaster software Version 2.0. Based on the study by Monastesse *et al.* [11], changes in the LUS score between the post induction period and arrival in the recovery room were correlated with changes in oxygenation (Spearman r = -0.43, P = .018). Based on the above parameters, with an alpha of 0.01 (2 sided) and power of 95%, the estimated sample size using the sample size formula for Regression methods - correlation coefficient was calculated to be 60. The collected data were analysed with IBM SPSS Statistics for Windows, Version 23.0. (Armonk, NY: IBM Corp). The descriptive statistics, frequency analysis, and percentage analysis were used for categorical variables and the mean, median, S.D, and IQR were used for continuous variables. To find the significant difference between the bivariate samples in paired groups the Wilcoxon signed rank test was used. For the multivariate analysis for repeated measures the Friedman test followed by Wilcoxon Signed rank test was used. In all the above statistical tools the probability value .05 is considered as significant level.

## Results and Discussion

Sixty patients scheduled to undergo laparoscopic surgery under general anaesthesia were assessed for eligibility and included in the study. There was no loss of follow-up during the study and all 60 patients were analyzed for results. Baseline characteristics of the patients included in the study were as listed in Table 2. Of the 60 patients included in the study, 27 were females and 33 were males. The surgeries included were Laparoscopic appendectomy, Laparoscopic Cholecystectomy, Laparoscopic umblical hernia repair, and Laparoscopic inguinal hernia repair. The sum of LUS was calculated in patients at all four-time intervals. The total LUS were increased significantly from T1 to T3, T1 to T4, T2 to T3, and T2 to T4 with a p-value of <0.001 (Table 3).

**Table 2.** Demographic parameters

| Parameters | Mean (SD) |
|---|---|
| Age | 45.4 (9.4) |
| Sex: Males/females (number) | 27/33 |
| Height (centimeters) | 159.4 (5.4) |
| Weight (kg) | 70.2 (5.2) |
| BMI | 27.7 (2.8) |
| ASA classification 1/2 (number) | 28/32 |
| Duration of Surgery (minutes) | 146.6 (18.0) |
| Duration of Anaesthesia (minutes) | 156.6 (18.1) |

**Table 3:** Total lung ultrasound scores in comparison with different time periods

| Time period | Z | P-value |
|---|---|---|
| TotalT2 - TotalT1 | $-1.732^{b}$ | 0.083 |
| TotalT3 - TotalT1 | $-6.594^{b}$ | 0.0005 |
| TotalT4 - TotalT1 | $-6.593^{b}$ | 0.0005 |
| TotalT3 - TotalT2 | $-6.595^{b}$ | 0.0005 |
| TotalT4 - TotalT2 | $-6.594^{b}$ | 0.0005 |
| TotalT4 - TotalT3 | $-1.414^{b}$ | 0.157 |

Since posterior quadrants (5 and 6) were observed to be involved more (Table 4), compared to the other regions and due to difficulties in statistical analysis of individual scores at all four-time intervals we compared individual scores of posterior quadrants (Table 5).

**Table 4:** Median values of LUS in different lung quadrants at different time periods

| Areas | T1 median /IQR | T2 median /IQR | T3 median /IQR | T4 median /IQR |
|---|---|---|---|---|
| R1 | 0(0-0) | 0(0-0) | 0(0-0) | 0(0-0) |
| R2 | 0(0-0) | 0(0-0) | 0(0-0) | 0(0-0) |
| R3 | 0(0-0) | 0(0-0) | 0(0-0) | 0(0-0) |
| R4 | 0(0-0) | 0(0-0) | 0(0-0) | 0(0-0) |
| R5 | 0(0-0) | 1(0-1) | 1(0-1) | 1(0-1) |
| R6 | 0(0-0) | 0(0-0) | 1(0-1) | 1(0-1) |
| L1 | 0(0-0) | 0(0-0) | 0(0-0) | 0(0-0) |
| L2 | 0(0-0) | 0(0-0) | 0(0-0) | 0(0-0) |
| L3 | 0(0-0) | 0(0-0) | 0(0-0) | 0(0-0) |
| L4 | 0(0-0) | 0(0-0) | 0(0-0) | 0(0-0) |
| L5 | 0(0-0) | 0(0-0) | 0(0-1) | 0(0-1) |
| L6 | 0(0-0) | 1(0-1) | 1(0-1) | 1(0-1) |

**Table 5:** Median values of LUS in dependent lung quadrants at different time periods

| Time period | R5 | | R6 | | L5 | | L6 | |
|---|---|---|---|---|---|---|---|---|
| | Z | P-value | z | P-value | Z | P-value | Z | P-value |
| T1–T2 | -2.44 | 0.014 | -1.00 | 0.317 | -2.64 | 0.008 | 0.00 | 1.0 |
| T1-T3 | -5.83 | <0.001 | -5.47 | <0.001 | -4.89 | <0.001 | -5.48 | <0.001 |
| T1-T4 | -5.91 | <0.001 | -5.47 | <0.001 | -4.47 | <0.001 | -5.48 | <0.001 |
| T2-T3 | -5.29 | <0.001 | - 5.385 | <0.001 | -4.12 | <0.001 | -5.48 | <0.001 |
| T2-T4 | -5.38 | <0.001 | - 5.385 | <0.001 | -2.83 | <0.001 | -5.48 | <0.001 |
| T3-T4 | -1.00 | 0.317 | 0.00 | <0.001 | -2.00 | 0.046 | 0.046 | 1 |

The incidence of overall atelectasis was calculated at all time-intervals at T1 6.6%, T2 6.6%, T3 78%, and T4 80%, which seems to be higher before extubation and 1 hour after surgery. We defined atelectasis to be significant if any region had the lung ultrasound score >/= 2 (Table 6).

There was no significant difference in the hemodynamics (HR and MAP) and oxygen saturations (SpO2) of all the patients at various time periods.

In this prospective observational study, it was found that lung ultrasound can be used intraoperatively for assessing the atelectasis degree. During general anaesthesia, patients are at increased risk of developing atelectasis, which gets even more worsen with laparoscopic surgery. Pneumoperitoneum along with trendelenberg position increases the intrathoracic pressure, reduces functional residual capacity causing atelectasis in dependent portions. In a study conducted by Acosta *et al.* [12], 88% developed atelectasis following general anaesthesia; they used MRI as a reference for diagnosing atelectasis and agreed that LUS can be used as an alternate for diagnosing atelectasis. Erol *et al.* [13] revealed the prevalence of atelectasis developing after laparoscopic bariatric surgery as 81%, postoperatively. We studied 60 patients who underwent laparascopic surgery under general anaesthesia. LUS scores used as an indicator at four-time intervals were compared. The atelectasis incidence increased at T3 (before extubation) and T4 (1 hour after extubation) with incidence of 78% and 80%, respectively. Furthermore, we clinically found that atelectasis increased more in lower lung areas. Hence, the posterior quadrants 5 and 6 were compared individually which showed significantly (p<0.001) higher LUS score at T3 and T4 time period. Similar findings were observed in study done by Erol *et al.* [13].

Hedenstierna *et al.* [5], examined the atelectasis mechanism developed in perioperative period and reported the incidence as 90%. The incidence of atelectasis in postoperative period were also similar 80%. Lee *et al.* [14] assessed perioperative atelectasis with different modes of ventilation. Total LUS was significantly higher in T3 (4.20) and T4 (1.77) compared to T1 (0.63). Liu *et al.* [15] studied effects of ultrasound guided lung recruitment maneuver on atelectasis in laparoscopic surgery. The atelectais incidence in control group where like our study as 76% and 81% at T3 and T4 time period, respectively. In addition, they performed lung ultrasound 24 hours after surgery; the incidence was decreased to 57%. Though atelectasis developed, it does not persist according to their study.

Although all the patients developed atelectasis according to the LUS over time, none of them developed clinical signs of failure in oxygenation or ventilation. This could be possibly due to the inclusion of only healthy adults in this study. None of the patients had any other postoperative pulmonary complications.

This study had some limitations. First, ultrasound is an operator -dependent imaging modality.

**Table 6:** Incidence of lung atelectasis according to LUS

| Time period | Patients (%) |
|---|---|
| T1 | 4(6.6) |
| T2 | 4(6.6) |
| T3 | 47(78%) |
| T4 | 48(80%) |

Hence, findings may vary based on observer. Second, ultrasound was used for diagnosing atelectasis, but it could not be compared with postoperative CT scan since it is not gold standard modality of investigation. Third, we followed up the patient until 1-hour postoperative period and could not evaluate the long-term results. Fourth, the criteria for substantial atelectasis were not yet established though many studies have used lung ultrasound as a diagnostic tool for atelectasis. Fifth, blood gases were not evaluated in this study rule out actual failure in oxygenation and ventilation.

## Conclusion

This study concluded that the incidence and degree of atelectasis as demonstrated by Perioperative Modified Lung ultrasound score increased over time, especially in the dependent posterior lung zones in adults undergoing laparoscopic surgery under general anesthesia. Although, atelectasis was demonstrated by ultrasound, there was no evidence of failure in oxygenation as demonstrated by clinical monitoring.

## Disclosure Statement

No potential conflict of interest was reported by the authors.

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## Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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