Section: Anaesthesiology

Original Research Article

ASSESSMENT OF PERIOPERATIVE ATELECTASIS IN LAPAROSCOPIC CHOLECYSTECTOMY AND LAPAROSCOPIC GYNAECOLOGICAL SURGERIES USING LUNG ULTRASOUND SCORE

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ABSTRACT

Background: Perioperative atelectasis poses significant challenges in surgical care, affecting patient outcomes following laparoscopic cholecystectomy and gynaecological surgeries. Effective assessment of atelectasis during these procedures remains crucial for optimizing perioperative management. **Materials and Methods:** After obtaining IEC clearance and CTRI registration, a prospective observational comparative study was conducted on 70 patients of age more than 18 years belonging to ASA PS I and II, posted for Laparoscopic Cholecystectomy (Group A) and Laparoscopic Gynaecological (Group B) procedures. Ultrasound of Lung was performed in supine position using linear array Sonosite transducer probe, 6-13 MHz placed longitudinally in 12 regions from right to left , cranial to caudal and anterior to posterior direction before induction of general Anaesthesia (T1), 5 minutes after pneumoperitoneum (T2), 15 minutes after shifting to recovery room (T3) and LUS (Lung Ultrasound Score) was calculated. **Result:** Welch's t-test (alpha 0.05) showed Group B had higher lung ultrasound scores in posterior quadrants post pneumoperitoneum, indicating atelectasis. Significant differences in left LQ5, LQ6, right RQ5, RQ6 ($p < 0.05$). Total lung score was higher in Group B (2.68, 95% CI: 2.06, 3.30) vs. Group A (0.28, 95% CI: 0.04, 0.51). **Conclusion:** Significant differences were in left and right posterior quadrants. Laparoscopic gynaecological surgeries present a higher risk of perioperative atelectasis compared to laparoscopic cholecystectomy, emphasizing need for targeted perioperative lung management.

INTRODUCTION

Approximately 90% of surgical patients develop perioperative atelectasis by loss of aeration following positive pressure mechanical ventilation.[1] Intra-abdominal pressure increases due to pneumoperitoneum during laparoscopic or robotic surgeries leading to an upward shift in the diaphragm, also a decrease in lung compliance,[2] which induces lung collapse and a decrease in functional residual capacity (FRC).[3] Aeration loss during pneumoperitoneum surgery in Trendelenburg position induces perioperative atelectasis, increased pulmonary vascular resistance (PVR) and possible development of postoperative pulmonary complications (PPCs) including pneumonia and acute lung injury.[4,5]

Effective management of emergencies such as atelectasis and pneumothorax, begins with quick and reliable diagnosis. Spirometry and radiography are known for their low accuracy and limitations. Point of care ultrasonography (POCUS) is becoming more widely used in modern anaesthesiology for detection of perooperative atelectasis.[6]

Bedside lung ultrasound (LUS) has the advantages of accuracy, sensitivity, non-invasiveness, non-radiation and convenience .It has been a powerful approach for the diagnosis of atelectasis, pleural effusion and pneumothorax, and assessing aeration loss in patients exhibiting hypoxemia in anaesthetized patients perioperatively.[6]

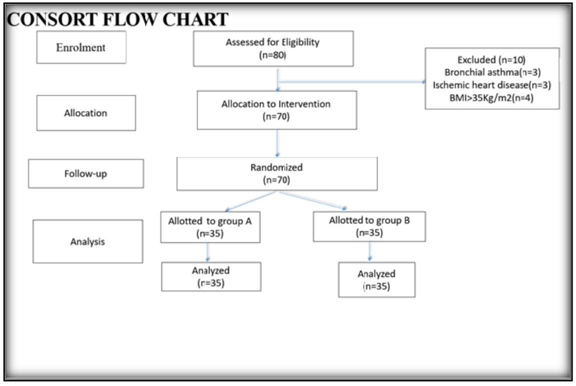
This study was conducted to compare the lung ultrasound score between laparoscopic gynaecological surgeries and laparoscopic cholecystectomy cases with a research question whether pneumoperitoneum causes higher incidence of lung atelectasis in patients undergoing elective laparoscopic gynaecological procedures when compared to patients undergoing laparoscopic cholecystectomy, during the perioperative.

The primary objective was to compare perioperative LUS score in twelve lung quadrants between laparoscopic cholecystectomy and laparoscopic gynaecological procedures. The secondary objectives were to observe intraoperative hemodynamic parameters and to observe for complications such as pneumothorax, endobronchial intubation and gas embolism.

MATERIALS AND METHODS

After obtaining approval from the Institutional Ethics Committee (IEC: 328), the study was registered with the Clinical Trial Registry of India (CTRI/2024/04/066235). A prospective observational comparative study was conducted at our tertiary care hospital from May 2023 to October 2023.The study was conducted as per the guidelines of the 'declaration of Helsinki, 2013'. Seventy ASA-PS I and II patients, aged more than 18 years, who were scheduled for elective laparoscopic cholecystectomy (Group A) and gynecological surgery (Group B), were divided into two groups of 35 patients each. Patients with chronic obstructive pulmonary disease diaphragmatic paralysis, previous thoracic surgeries, neuromuscular diseases, cardiac diseases and BMI >35kg/m2 were excluded from the study.

CONSORT FLOW CHART



The ultrasonography was done in patients in supine position. The lung area was divided into six quadrants with longitudinal (anterior, posterior axillary lines) and axial lines (nipple line). Each lung quadrant is numbered as one to six from caudal to cranial direction and divided into anterior (1,2), lateral(3,4), and posterior (5,6) axis by longitudinal line. The depth was adjusted in individual cases while finding two adjacent ribs to obtain the image of pleura which is called 'bat sign' and finding two adjacent B-lines with synchronized movement of the pleura. Scoring is done based on Modified Lung ultrasound with a minimum of 3 and maximum of 36.[7] Each quadrant ranged from 0 to 3. Addition of all the quadrants will give us the respective results.

Modified Lung ultrasound score:

- 0- normal aeration. 0-2 B lines.
- 1- small loss of aeration.> 3 B lines or multiple small subpleural consolidations separated by a normal pleural line quadrant
- 2- moderate loss of aeration. Multiple coalescent B lines or multiple small subpleural consolidation separated by thickened or irregular pleural line.
- 3- severe loss of aeration. Consolidation or small subpleural consolidation > 1 x 2 cm in diameter.

Pulmonary atelectasis was considered as significant when LUS is >2 in any region.[8]

The above scoring was compared between laparoscopic cholecystectomy procedures and laparoscopic gynaecological cases.

The anaesthetic technique is standardized for all patients. On the previous day of surgery, thorough pre-anaesthetic evaluation of the patient was done. On the day of surgery the patient was explained about the study protocol and written informed consent for study and publication was taken for the same. In the pre-operative room after conforming Nil per oral status, intravenous (IV) cannula was secured and preloaded with intravenous crystalloids (10ml/kg). After shifting patient to operation theatre (OT) standard monitors were established and baseline vitals such as Heart Rate (HR), Systolic Blood Pressure (SBP), Diastolic Blood pressure (DBP), Mean Arterial Pressure (MAP) Saturation (SpO2) were recorded and noted down. Premedication with intravenous Inj.Ondansetron 0.01mg/kg and Inj.Midazolam 0.05mg/kg was adminstered. Anaesthesia was induced using standard anaesthetic drugs. Uniformly in all patients non depolarizing muscle relaxant was used for tracheal intubation and muscle relaxant was repeated to maintain adequate relaxation during surgery. A tidal volume of 6ml/kg predicted body weight, positive end expiratory pressure (PEEP) of 0 cm of H2O was used in both groups. Intra-abdominal pressure was maintained at 14 mm hg, Reverse trendelenberg of 150 in group A, trendelenberg position of 300 in group B was used.

After taking necessary aseptic precautions a high frequency linear array Sonosite transducer probe of 13-6 MHz was placed longitudinally and horizontally along the intercostal space. These 6 regions on either side were examined from right to left , cranial to caudal direction and anterior to posterior directions in supine position and LUS was calculated. The LUS was performed at pre-determined time points, namely T1 (before induction of general Anaesthesia), T2 (5 minutes after pneumoperitoneum), T3 (15 minutes after shifting to recovery room) respectively.

Sample Size

$$n = \frac{(Z_\alpha + Z_\beta)^2 \times \sigma^2}{d^2}$$

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The size of the effect that is clinically worthwhile to detect (d) = 15
The probability of falsely rejecting a true null hypothesis (α) = 0.005, Zα = 1.96
The probability of failing to reject a false null hypothesis (β) = 0.80, Zβ = 0.84
Standard Deviation of the population being studied (SD) or (σ) = 30.5 from a published study (Lee YY, Han JI.,[8]) was calculated and a sample size of 32 was obtained in each group. Considering possible dropouts, 35 patients were allotted in each group.
Statistical analysis: Descriptive statistics was performed to assess the mean and standard deviation of the respective groups.
Test for statistical significance between the groups was performed using Independent two-sample t -test (Welch's t-test) with Significance Level (alpha) set at 0.05
For p-value < 0.05, we find evidence to reject the null hypothesis of a significant difference between the two groups.

RESULTS

The demography and perioperative characteristics such as duration of surgery, pnemoperitonieum, ventilation parameters and intra-abdominal pressures were similar in both groups.
Total LUS was calculated at each time points and noted. At T1 no measurable differences between the two groups was observed with. LUS=0, CI=0.

Table 1: Patient data & perioperative characteristics

	Group A (n=35)	Group B (n=35)
Age	40.36 ± 12.76	39.71 ± 11.02
Weight	60.16 ± 6.25	59.6 ± 5.84
Height	163.08 ± 5.96	159.43 ± 3.34
BMI	22.63 ± 2.24	23.48 ± 3.89
ASA Class I/II	23/13	25/10
Duration of Surgery, minutes	80.14 ± 14.42	72.14 ± 24.83
Duration of Pneumoperitoneum, minutes	66.25 ± 12.5	63 ± 23.36
Intra-abdominal Pressure	14 mm Hg	14 mm Hg
Pneumo P-peak	27.75 ± 3.79	27.43 ± 2.99
Pneumo Compliance	21.05 ± 0.79	19.65 ± 1.21
Pnuemo ETCO2	29.05 ± 2.26	28.57 ± 3.49

Table 2: Lung ultrasound score – group a (laparoscopic cholecystectomy) left

	T2			T3		
Lung QDT	**Mean lung Score**	**SD**	**CI95**	**Mean lung score**	**SD**	**CI95**
Ant LQ1	0	0	(0, 0)	0	0	(0, 0)
Ant LQ2	0	0	(0, 0)	0	0	(0, 0)
Lat LQ3	0	0	(0, 0)	0	0	(0, 0)
Lat LQ4	0	0	(0, 0)	0	0	(0, 0)
Post LQ5	0.06	0.23	(-0.02, 0.13)	0	0	(0, 0)
Post LQ6	0.08	0.28	(-0.01, 0.18)	0.03	0.17	(-0.03, 0.08)
Right						
Ant RQ1	0	0	(0, 0)	0	0	(0, 0)
Ant RQ2	0	0	(0, 0)	0	0	(0, 0)
Lat RQ3	0	0	(0, 0)	0	0	(0, 0)
Lat RQ4	0	0	(0, 0)	0	0	(0, 0)
Post RQ5	0.03	0.17	(-0.03, 0.08)	0.03	0.17	(-0.03, 0.08)
Post RQ6	0.11	0.32	(0.0, 0.22)	0	0	(0, 0)

Table 3: Lung Ultrasound Score – Group B (Laparoscopic Gynecological Surgeries) LEFT

	T2			T3		
Lung QDT	**Mean lung score**	**SD**	**CI95**	**Mean lung score**	**SD**	**CI95**
Ant LQ1	0	0	(0, 0)	0	0	(0, 0)
Ant LQ2	0	0	(0, 0)	0	0	(0, 0)
Lat LQ3	0	0	(0, 0)	0	0	(0, 0)
Lat LQ4	0	0	(0, 0)	0	0	(0, 0)
Post LQ5	0.71	0.46	(0.56, 0.87)	0.09	0.28	(-0.01, 0.18)
Post LQ6	0.54	0.51	(0.37, 0.72)	0	0	(0, 0)
Right						
Ant RQ1	0	0	(0, 0)	0	0	(0, 0)
Ant RQ2	0	0	(0, 0)	0	0	(0, 0)
Lat RQ3	0	0	(0, 0)	0	0	(0, 0)
Lat RQ4	0	0	(0, 0)	0	0	(0, 0)
Post RQ5	0.63	0.49	(0.46, 0.8)	0.09	0.28	(-0.01, 0.18)
Post RQ6	0.71	0.46	(0.56, 0.87)	0.03	0.17	(-0.03, 0.09)

Table 4: each quadrant lung ultrasound score – left

LUNG QDT	LUS (A)	SD A	LUS (B)	SD B	p-value
Before Induction	0	0	0	0	-
T2 - Left Lung					
Ant LQ1	0	0	0	0	-
Ant LQ2	0	0	0	0	-
Lat LQ3	0	0	0	0	-
Lat LQ4	0	0	0.09	0.28	0.06
Post LQ5	0.06	0.23	0.71	0.46	0.00
Post LQ6	0.08	0.28	0.54	0.51	0.00
Total	0.14 (0.02, 0.26)	0.35	1.34 (1.03, 1.65)	0.9	0.00
T3 - Left Lung					
LUNG QDT	LUS (A)	SD (A)	LUS (B)	SD (B)	p-value
Ant LQ1	0	0	0	0	-
Ant LQ2	0	0	0	0	-
Lat LQ3	0	0	0	0	-
Lat LQ4	0	0	0	0	-
Post LQ5	0	0	0.09	0.28	0.06
Post LQ6	0.03	0.17	0	0	0.29
Total	0.03 (-0.03, 0.08)	0.17	0.17 (-0.02, 0.37)	0.56	0.16

Table 5: Each quadrant lung ultrasound score – right

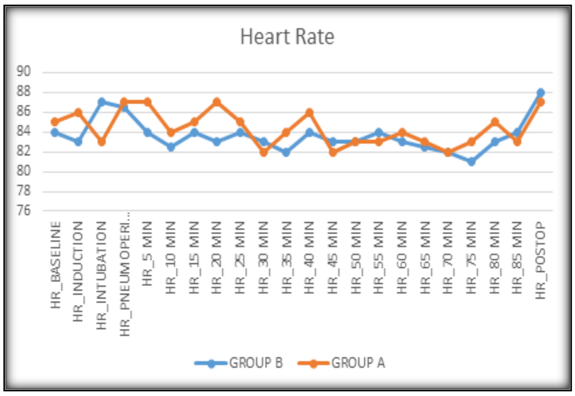
T2 - Right Lung					
LUNG QDT	**LUS (A)**	**SD (A)**	**LUS (B)**	**SD (B)**	**p-value**
Ant RQ1	0	0	0	0	-
Ant RQ2	0	0	0	0	-
Lat RQ3	0	0	0	0	-
Lat RQ4	0	0	0	0	-
Post RQ5	0.03	0.17	0.63	0.49	0.00
Post RQ6	0.11	0.32	0.71	0.46	0.00
T2 - Total Right Lung					
	LUS (A)	**SD (A)**	**LUS (B)**	**SD (B)**	**p-value**
Total	0.14 (0.02, 0.26)	0.35	1.34 (1.03, 1.65)	0.9	0.00
T3 - Right Lung					
LUNG QDT	**LUS (A)**	**SD (A)**	**LUS (B)**	**SD (B)**	**p-value**
Ant RQ1	0	0	0	0	-
Ant RQ2	0	0	0	0	-
Lat RQ3	0	0	0	0	-
Lat RQ4	0	0	0.09	0.28	0.06
Post RQ5	0.03	0.17	0.09	0.28	0.28
Post RQ6	0	0	0.03	0.17	0.30
T3 - Total Right Lung					
	LUS (A)	**SD (A)**	**LUS (B)**	**SD (B)**	**p-value**
Total	0.03 (-0.03, 0.08)	0.17	0.2 (-0.0006, 0.4)	0.58	0.10

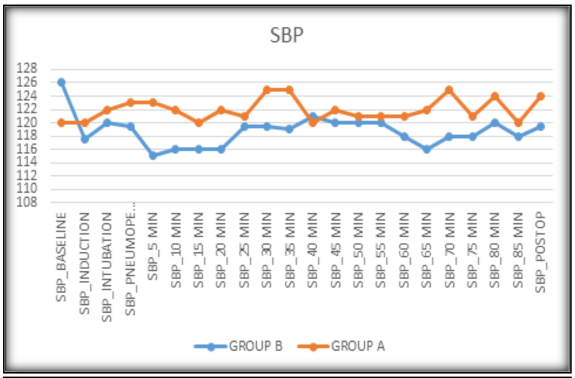
Lung Quadrant	**LUS Mean ± SD**	**95% Confidence Interval**		**Min**	**Max**	**p-value**
		Lower CI (95%)	**Upper CI (95%)**			
T2 - Left Lung						
Ant LQ1	0.00 ± 0.00	0	0	0	0	-
Ant LQ2	0.00 ± 0.00	0	0	0	0	-
Lat LQ3	0.00 ± 0.00	0	0	0	0	-
Lat LQ4	0.045 ± 0.20	-0.0015	0.0915	0	0.37	0.06
Post LQ5	0.385 ± 0.345	0.27	0.5	0	1.17	0
Post LQ6	0.31 ± 0.395	0.179	0.441	0	1.05	0
Total	0.74 ± 0.625	0.525	0.955	-0.21	2.24	0
T3 - Left Lung						
Ant LQ1	0.00 ± 0.00	0	0	0	0	-
Ant LQ2	0.00 ± 0.00	0	0	0	0	-
Lat LQ3	0.00 ± 0.00	0	0	0	0	-
Lat LQ4	0.045 ± 0.20	-0.0015	0.0915	0	0.37	0.06
Post LQ5	0.045 ± 0.20	-0.0015	0.0915	0	0.37	0.06
Post LQ6	0.015 ± 0.085	-0.013	0.043	0	0.2	0.29
Total	0.1 ± 0.365	-0.055	0.255	-0.14	0.73	0.16
T2 - Right Lung						
Ant RQ1	0.00 ± 0.00	0	0	0	0	-
Ant RQ2	0.00 ± 0.00	0	0	0	0	-
Lat RQ3	0.00 ± 0.00	0	0	0	0	-
Lat RQ4	0.00 ± 0.00	0	0	0	0	-
Post RQ5	0.33 ± 0.33	0.236	0.424	0	1.12	0
Post RQ6	0.41 ± 0.39	0.287	0.533	0	1.17	0
Total	0.74 ± 0.625	0.525	0.955	-0.21	2.24	0

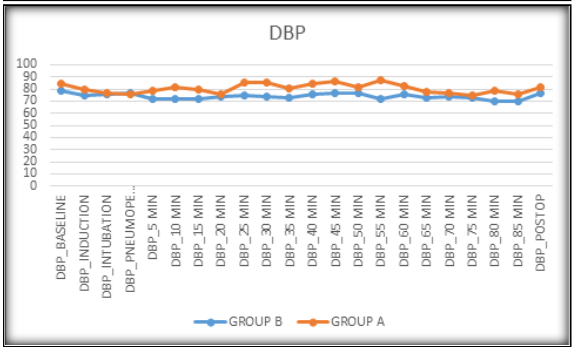
T3 - Right Lung						
Ant RQ1	0.00 ± 0.00	0	0	0	0	-
Ant RQ2	0.00 ± 0.00	0	0	0	0	-
Lat RQ3	0.00 ± 0.00	0	0	0	0	-
Lat RQ4	0.045 ± 0.20	-0.0015	0.0915	0	0.37	0.06
Post RQ5	0.06 ± 0.225	0.0175	0.1025	0	0.37	0.28
Post RQ6	0.015 ± 0.085	-0.013	0.043	0	0.2	0.3
Total	0.115 ± 0.375	-0.0225	0.2525	-0.14	0.6	0.1

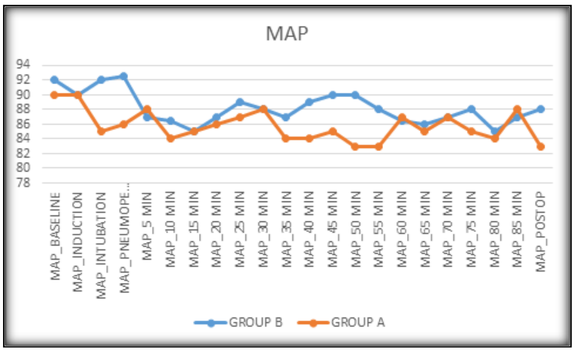
Ant LQ1, Ant LQ2, and Lat LQ3 Lat LQ4: Both Group A and Group B had no notable differences, as the mean lung ultrasound scores (LUS) for these regions were 0.00, with no variability between the groups. Post LQ5: This area showed a significant increase in LUS for Group B (mean 0.71 ± 0.46), compared to Group A (mean 0.06 ± 0.23). The confidence interval for Group B (0.558, 0.862) indicates a statistically significant difference between the two groups (p-value = 0.00). Post LQ6: Group B had a much higher mean LUS (0.54 ± 0.51) compared to Group A (0.08 ± 0.28). The confidence interval for Group B (0.371, 0.709) suggests that the increase in LUS is significant (p-value = 0.00).Total Left Lung: For the total left lung, Group B had a considerably higher mean LUS (1.34 ± 0.90) than Group A (0.14 ± 0.35). The confidence interval for Group B (1.042, 1.638) shows a significant difference between the two groups (p-value = 0.00).

In summary, Group B exhibited significantly higher lung ultrasound scores, particularly in the posterior quadrants and the total lung, suggesting a greater degree of perioperative atelectasis compared to Group A. This is most notable after pneumoperitoneum, with statistically significant differences in certain lung regions, particularly posterior regions in Group B. There was no significant difference in hemodynamic parameters between the groups. Complications like pneumothorax, endobronchial intubation and gas embolism was not seen in both groups.









DISCUSSION

Lung atelectasis is a frequent complication that necessitates the attention of anesthesiologists. Early detection and management are crucial for effective treatment. Additionally, identifying potential risk factors can facilitate closer monitoring, leading to improved outcomes in patients at higher risk for developing atelectasis. This study focuses on whether the incidence of lung atelectasis is more in the trendelenberg than the reverse trendelenberg position using LUS.

The study demonstrated that both volume-controlled ventilation (VCV) and pressure-controlled ventilation with volume guarantee (PCV-VG) led to an increase in lung ultrasound scores (LUS) from baseline during surgery.[1] This is likely due to the combined effects of pneumoperitoneum and the Trendelenburg position, which are known to elevate intrathoracic pressure and reduce functional residual capacity, particularly affecting the dependent portions of the lungs. The posterior lung quadrants appeared more susceptible to atelectasis formation under these conditions, which is consistent with findings in robotic gynecologic surgeries. The prolonged requirement for pneumoperitoneum and Trendelenburg positioning during these procedures may contribute significantly to perioperative atelectasis, emphasizing the need for careful intraoperative management to minimize respiratory complications. In this study, it was observed that the posterior lung quadrants were particularly prone to atelectasis following the induction of pneumoperitoneum. Both the right and left posterior lung regions exhibited notable differences between the two groups. These findings suggest that pneumoperitoneum, in combination with the Trendelenburg position, exacerbates atelectasis formation in the dependent portions of the lungs. The varying degrees of collapse in the posterior lung regions between groups highlight the impact of ventilatory strategies during surgery. This underscores the importance of optimizing ventilation to reduce the incidence of atelectasis, particularly in procedures requiring prolonged pneumoperitoneum and Trendelenburg positioning, as seen in robotic gynecologic surgeries.

Changes in lung ultrasound (LUS) scores during surgery have been associated with alterations in oxygenation, as demonstrated by Monastesse et al,[3] where a negative correlation between LUS score and oxygenation was noted from post-induction to recovery (Spearman r = -0.43, p = 0.018). Their study showed a progressive worsening of LUS scores following general anesthesia induction, with the most pronounced changes in the basal and dependent lung zones. Similarly, in laparoscopic cholecystectomy, patient positioning—particularly the reverse Trendelenburg position—contributed to higher LUS scores in specific lung quadrants, indicating that body position significantly influences atelectasis development.

Our study showed after pneumoperitoneum, the LUS scores in certain lung quadrants show statistically significant changes, indicating atelectasis formation. However, by 15 minutes after extubation, most LUS scores have returned to baseline levels, and the observed differences are not statistically significant. The significant changes observed immediately after pneumoperitoneum suggest that patient positioning and pneumoperitoneum induce atelectasis.

After pneumoperitoneum, the patient was positioned in a reverse Trendelenburg position with the operating table angled toward the left during laparoscopic cholecystectomy. In both the right and left lungs, LUS scores were done per quadrant. At the time of conclusion of operation i.e. before extubation, the inferolateral, superoposterior, and inferoposterior quadrants of both the right and left lung had a greater LUS score.[2]

The posterior quadrants in both the left and right lung fields showed higher LUS scores at the time of pnemoperitonieum which was higher in laparoscopic gynaecological procedures when compared to laparoscopic cholecystectomy procedure.

A Prospective randomised study found that combining ultrasound-guided recruitment maneuvers (RM) with PEEP reduced atelectasis incidence in the PACU compared to PEEP alone, but this difference disappeared after 24 hours. In the PACU, atelectasis decreased from 81.8% in the control group to 40% in the RM group, with no differences in oxygen saturation or length of stay. The short-term effect of RM on intraoperative atelectasis was minimal, likely due to persistent factors like patient positioning. RM may not be necessary for healthy patients undergoing laparoscopic surgery due to potential risks, though it offers potential benefits for high-risk patients. Ultrasound-guided monitoring of lung aeration could be valuable for future research in mechanical ventilation.

All ultrasound examinations were successfully completed for every patient, with 1680 cine loops acquired. At baseline (T0), the highest LUS scores were observed in the posterior lung zones of both groups. After recruitment maneuvers (T1), the CPRM group showed the most significant improvement in LUS scores for the posterior lung zones, while no notable changes were observed in the control group. Globally, LUS scores were similar between the two groups at baseline, but after recruitment, a significant reduction in LUS scores was seen in the CPRM group, indicating improved lung aeration, whereas the control group showed no significant change.

Haemodynamic parameters were such as heart rate, SBP, DBP, MAP were recorded and noted at defined time points. They were stable and no clinical significant change in the parameter was noted in cases undergoing laparoscopic cholecystectomy.[2]

In our study the haemodynamic parameters were noted between the two groups A & B at defined time points and recorded respectively and showed no significant difference between the two groups.

Patient positioning during surgery, often involving extreme Trendelenburg or reverse Trendelenburg, can lead to significant physiological effects. In steep Trendelenburg, risks include cerebral and upper airway edema, worsened ventilation-perfusion mismatch, and tracheal tube migration. A rare but serious complication is well leg compartment syndrome, caused by impaired lower limb perfusion and venous compression, especially in surgeries lasting over 4 hours. Preventive measures include repositioning the patient every 2 hours, leg massage, and avoiding certain supports. In reverse Trendelenburg, the head-up position reduces venous

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return, increasing the risk of hypotension and ischemia, particularly in elderly or hypovolemic patients.[5-11]

CONCLUSION

The study demonstrates that the incidence of atelectasis after pneumoperitoneum is higher in laparoscopic gynaecological surgeries when compared to laparoscopic cholecystectomy cases during the perioperative period.

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