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ORIGINAL RESEARCH

Evaluation of effect of lung recruitment manoeuvres on perioperative atelectasis in laproscopic cholecystectomies: a randomised controlled trial

[1]Dr. Apurva Kumari, [2]Dr. Vidya Patil, [3]Dr. Anusha Suntan, [4]Dr. M M Patil

[1]Post Graduate, [2]Professor, [3]Assistant Professor, Department of Anaesthesiology, BLDE (DU) Shri B M Patil Medical College Hospital and Research Centre, Vijayapura, Karnataka, India
[4]Professor and HOD, Department of Pediatrics, BLDE (DU) Shri B M Patil Medical College Hospital and Research Centre, Vijayapura, Karnataka, India

Corresponding Author
Dr. Anusha Suntan
Assistant Professor, Department of Anaesthesiology, BLDE (DU) Shri B M Patil Medical College Hospital and Research Centre, Vijayapura, Karnataka, India

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ABSTRACT

Background: The majority of patients undergoing general anaesthesia develop atelectasis, especially following laparoscopic cholecystectomy. During laparoscopic procedures, pneumoperitoneum impairs pulmonary function, resulting in noticeable atelectasis. The lung recruitment technique may reduce postoperative pulmonary complications and hypoxia from atelectasis. **Methods:** The patients were classified randomly. Group UC did not receive lung recruitment, while Group URM did. All patients underwent ultrasonography at four-time points: T1 - just before anaesthesia induction, T2 – before extubation, T3 - 15 minutes post-extubation, and T4 - 30 minutes post-extubation. Only patients of the URM group have received lung recruitment directed by real-time ultrasound. Ultrasonic scanning showed the absence of collapsed areas following manual adjustment of airway pressure from 10 cmH2O to 20 cmH2O, with a FiO2 of 0.4. After the surgery, patients in both groups were assessed for any ongoing atelectrauma and desaturation. **Conclusion:** At T3 and T4, the URM group exhibited a significantly reduced aeration loss of 22% and 51%, respectively, compared to the UC group, which showed losses of 53% and 87% ($p < 0.01$). The URM group exhibited better oxygenation post-surgery than the UC group, with mean SpO_2 values of 98.10 ± 1.744% versus 94.54 ± 1.286% ($p = 0.001$). The increased alveolar recruitment and gas exchange in the URM group accounted for this outcome. In conclusion, using ultrasound to facilitate lung recruitment may decrease atelectasis during surgeries, improve oxygenation, and enhance pulmonary outcomes in laparoscopic cholecystectomy.

Keywords: Perioperative Atelectasis, Lung Recruitment Manouevre, Laproscopic Cholecystectomy

INTRODUCTION

Atelectasis is a prevalent perioperative complication among patients undergoing laparoscopic procedures after receiving general anaesthesia [1, 2]. Reduced lung compliance, impaired oxygenation, increased pulmonary vascular resistance, and potential lung injury might result from such a surgery that induces atelectasis [3]. In turn, lung recruitment maneuvers (LRM) and other effective preventative techniques to reduce atelectrauma have become increasingly prevalent in anaesthetic treatment due to their substantial impact [4].

The purpose of lung recruitment techniques during mechanical ventilation is to briefly increase airway pressure in order to expand closed alveoli and improve lung mechanics and oxygenation [5]. Various tactics for pulmonary recruitment maneuvers, including persistent inflation and stepwise PEEP (positive end-expiratory pressure) titration, remain unvalidated procedures and are currently under research [6, 7]. With advancements in ultrasound-guided lung recruitment manoeuvres, a precise assessment of aeration loss and alveolar collapse has become feasible, offering a non-invasive, real-time evaluation tool [8, 9].

Laparoscopic procedures require pneumoperitoneum, which makes it difficult for the lungs to expand and leads to atelectasis, which will add to the problem.

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The prevalence of atelectasis is higher in laparoscopic procedures. Studies show that high intra-abdominal pressure lowers functional residual capacity (FRC) and makes it more likely for dependent lungs to collapse [10]. As a result, many studies have suggested LRM as a good way to fight hypoxia caused by atelectasis and pulmonary complications after surgery [11].

Several processes cause athelectasis, but the most important ones are absorption, compression, and surfactant dysfunction [12]. When oxygen replaces nitrogen in alveoli, it collapses because it cannot hold more air [13]. Compression atelectasis happens when pressure on the alveoli from the outside is due to pneumoperitoneum, the Trendelenburg position, and less diaphragmatic movement [14]. Surfactant dysfunction, which is often made worse by anaesthesia, makes alveoli unstable, which leads to the progressive collapse of the alveoli [15].

Atelectasis causes more pulmonary shunting, a mismatch between ventilation and perfusion, less lung compliance, and poor gas exchange. These all make patients more likely to have hypoxemia and respiratory problems after surgery [16, 17]. There is a direct link between the amount of atelectasis before surgery and the number of pulmonary complications that happen after surgery, such as pneumonia, prolonged mechanical ventilation, and acute respiratory distress syndrome (ARDS) [18, 19].

LRM is a lung-protective ventilation strategy to restore alveolar patency and improve oxygenation [20]. Two principal methods—sustained inflation and stepwise PEEP recruitment—have been explored for efficacy in perioperative settings [21]. Sustained inflation is when a single high-pressure breath (30–40 cmH_2O) holds for 10–30 seconds, which causes the collapsed alveoli to re-expand [22]. Stepwise PEEP recruitment is an alternative method that involves gradually raising PEEP levels (from 5 cmH_2O to 15 cmH_2O or more) to improve alveolar recruitment while keeping the blood flow stable [23]. Luo et al. (2020) meta-analysis found that stepwise PEEP recruitment was better than sustained inflation at keeping oxygen levels high and lowering atelectasis after surgery [24].

Ultrasound imaging of the lungs has become a quick, radiation-free, and accurate way to find atelectasis before surgery [25]. Lung ultrasound (LUS) makes it possible to see how efficiently recruitment works in real-time, which lets doctors adjust PEEP and inspiratory pressures for each patient [26].

Studies that compare ultrasound-guided LRM to regular LRM have shown that the former leads to better alveolar recruitment, less severe atelectasis, and better oxygenation [27, 28]. Lee et al. (2020) found that using ultrasound to guide lung recruitment cut the risk of atelectasis after surgery by 30% compared to other methods [29].

Clinical evidence supporting lung recruitment in laparoscopic surgery- Several randomised controlled trials (RCTs) have evaluated the role of LRM in laparoscopic cholecystectomy. Wu et al. (2022) found that ultrasound-guided LRM significantly reduced aeration loss and improved intraoperative oxygenation in laparoscopic gynaecological surgeries [3]. Shono et al. (2020) found that higher PEEP levels (15 cmH_2O) improved regional ventilation and kept the mechanics of the lungs during pneumoperitoneum [1].

Atelectasis remains a primary perioperative concern, with significant implications for patient recovery and postoperative pulmonary function. Lung recruitment manoeuvres, particularly ultrasound-guided approaches, offer a promising intervention for reducing atelectasis and improving oxygenation. This study aims to provide strong clinical evidence on how well ultrasound-guided lung recruitment works in laparoscopic cholecystectomy, which will help improve ventilation strategies during surgery.

AIMS AND OBJECTIVES

This research aims to assess the efficacy of the lung recruitment manoeuvre in reducing the risk of lung injury during laparoscopic cholecystectomy performed under general anaesthesia. Our main goal is to detect atelectasis and assess the level of aeration loss using ultrasonography. As secondary goals, we have compared the two groups' lung ultrasonography scores, determine if there are any B lines right after surgery, and see how the recruiting manoeuvre affects blood flow.

MATERIALS AND METHODS

Method of collection of data

Source of data

A study was conducted by the Department of Anesthesiology at Shri B. M. Patil Medical College, Vijayapura, BLDEU, on lung recruitment manoeuvres (LRM) and atelectasis in patients who were undergoing elective laparoscopic cholecystectomy under general anaesthesia. This prospective, randomised, controlled study is conducted from February 2024 to December 2024. The patients were randomly assigned to two groups using a computer-generated process. The URM Group comprises patients who undergo real-time ultrasound-guided lung recruitment techniques, while the UC Group implements conventional ventilation strategies that do not involve recruitment manoeuvres.

Sample size

The sample size was estimated using G*Power version 3.1.9.4 software based on prior studies evaluating lung ultrasound scores in lung recruitment manoeuvres. With measurements from Time Point T3 (UC Group Mean = 10.77, SD = 1.57; URM Group Mean = 9.33, SD = 0.96), we have found that we needed 82 patients (41 in each group) to achieve a power of 99% at a 1% level of significance.

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Statistical analysis

Excel captured data, and SPSS (20) evaluated it. We displayed the results as mean, SD, percentages, and graphs. We used an independent sample t-test to distribute continuous data regularly. We have used the Mann-Whitney U test for non-normally distributed variables and employed Chi-square or Fisher's exact tests for categorical variables. A p-value < 0.05 indicates significance.

Ethical consideration

The Institutional Ethics Committee has approved this study, which complies with Good Clinical Practice (GCP) guidelines and the Declaration of Helsinki. All participants signed informed consent forms, and we strictly upheld the confidentiality of their data.

Study population

The study included patients with ASA Grade I and II who were undergoing elective laparoscopic cholecystectomy under general anaesthesia of either gender, aged 18 to 60 years. Exclusion criteria include patient refusal to participate in the trial, a body mass index (BMI) over 35 kg/m², a prior abdominal or thoracic surgery history, and patients with pre-existing restrictive or obstructive pulmonary disorders.

METHODOLOGY

Pre-anaesthetic evaluation

In order to prepare each patient for surgery, we took their medical history, performed a thorough physical examination, and analysed their lung function using a preoperative baseline lung ultrasound. Lab work includes a complete blood count, kidney function tests, serology, blood sugar, electrocardiogram, and chest x-ray.

Perioperative protocol

We acquired informed consent before the procedure and confirmed nil by mouth for six hours. We randomly assigned all patients into one of two groups: Group UC, which did not receive any lung recruitment manoeuvre, and Group URM, which received an ultrasound-guided lung recruitment manoeuvre. All patients received a lung examination through ultrasonography before induction (T1). Before performing endotracheal intubation, we pre-oxygenated all patients with 100% O_2 for three minutes, and then they induced general anaesthesia. Hemodynamic parameters were monitored and recorded during the surgical procedure. Following the end of the procedure before endotracheal extubation, a lung examination was performed using ultrasonography for all patients (T2), and members of the URM group received a lung recruitment manoeuvre under direct real-time ultrasound guidance. A gradual increase in airway pressure from 10 cmH_2O to 20 cmH_2O with a FiO_2 of 0.4 was applied manually until no collapsed regions were visible on ultrasonic imaging. At 15 (T3) and 30 (T4) minutes post-extubation, all patients underwent lung examination through ultrasonography to evaluate for recurrence of atelectrauma during the postoperative period and monitored for any postoperative desaturation.

OBSERVATIONS AND RESULTS

This research looked at how ultrasound-guided lung recruitment maneuvers (LRM) affected atelectasis during a laparoscopic cholecystectomy in patients. The findings are displayed in tabular and graphical formats to emphasize significant statistical comparisons between the control group (UC) and the intervention group (URM).

Table no. 1: Baseline parameters

BASELINE PARAMETERS			
	GROUP UC	GROUP URM	P VALUE
AGE (Yr)	49.12±17.222	42.24±15.211	0.039
SEX (M/F)	26/15	29/12	
Weight (kg)	64.83±12.857	68.83±13.164	0.198
ASA GRADE I/II	26/15	32/9	
DOS (min)	86.34±40.405	96.34±61.135	0.834
DOA (min)	101.59±39.944	109.76±62.878	0.936
DOS: Duration of surgery; DOA: Duration of anaesthesia			

The two groups (UC and URM) had similar baseline characteristics, including age, sex distribution, weight, and ASA grade, ensuring comparability for study outcomes.

The duration of surgery and anaesthesia was marginally extended in the URM group; however, this difference lacked statistical significance, suggesting that lung recruitment manoeuvres did not meaningfully extend the procedure time.

Table no. 2: Intraoperative hemodynamic and ventilator parameters

INTRA-OPERATIVE HEMODYNAMIC AND VENTILATOR PARAMETERS			
PARAMETERS	UC GROUP	URM GROUP	P VALUE
HR (bpm)	78.88±10.854	79.85±7.528	0.709
SYS BP (mmHg)	128.34±13.152	128.20±22.198	0.381

DIAS BP (mmHg)	79.32±7.33	79.27±8.388	0.694
SPO2 (%)	100±0.0	100±0.0	1
ETCO2	36.24±1.410	36.44±1.433	0.637
VT (ml)	441.71±39.994	449.27±36.083	0.355
PEEP (cmH2O)	5±0.0	5.10±0.436	0.155
P PLAT (cmH2O)	16.02±1.405	15.78±1.636	0.349
PEAK (cmH2O)	23.02±1.604	23.68±1.753	0.07
MV (ml/min)	4.837±0.9046	4.683±8.8792	0.305
HR: Heart rate; BP: blood pressure; SPO2: Saturation of peripheral oxygenation; ETCO2: End tidal carbon dioxide			
VT: Tidal volume; PEEP: Positive end-expiratory pressure; P PLAT: Plateau pressure; PEAK: Peak inspiratory pressure; MV: Minute ventilation			

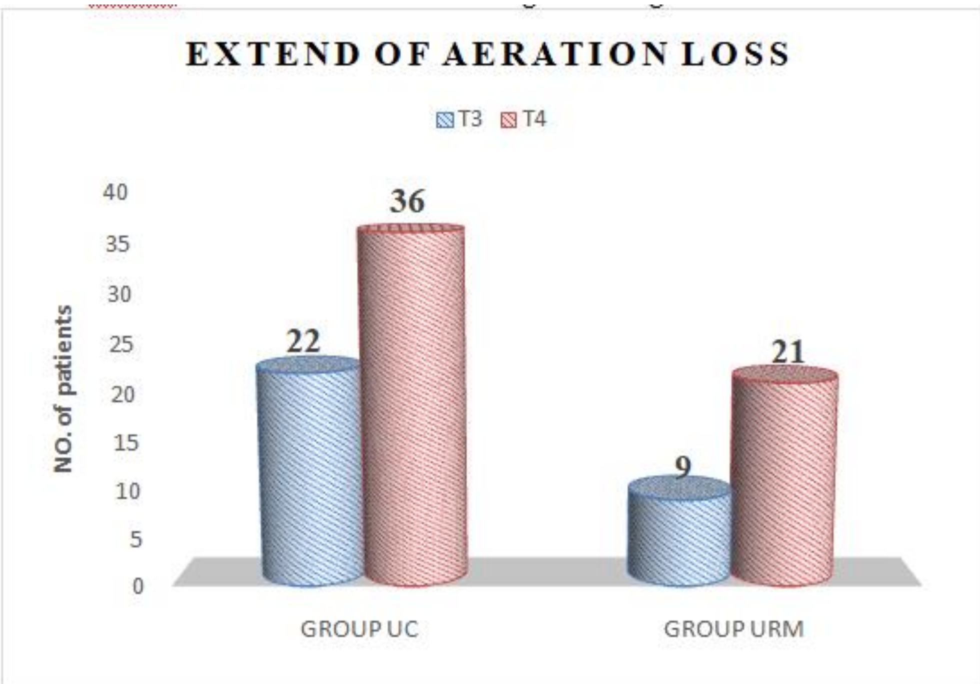
No significant differences between the two groups were observed in systolic and diastolic blood pressure, heart rate, or intraoperative oxygen saturation (SpO2). This indicates that lung recruitment maneuvers did not negatively impact hemodynamic stability.

It seemed that lung recruitment did not add any extra work to the ventilatory system or increase the risk of barotrauma because the tidal volumes, peak inspiratory pressures, plateau pressures, and PEEP levels were similar between the two groups.

Table no. 3: Recruitment Manouvre (RM)

RECRUITMENT MANOEUVRES (RM)			
		GROUP URM	**P VALUE**
NO. OF RM	2	2	0.605
	3	19	
	4	14	
	5	6	
INFALTION PRESSURE	10 cmH2O	21	0.466
	15 cmH2O	16	
	20 cm H20	4	

Most of the patients in the URM group needed three to four recruitment maneuvers, with inflation pressures ranging from 10 to 20 cmH₂O. This shows that ultrasound-guided lung recruitment can work without using too much pressure.



Graph 1: A bar chart representation of Extend of Aeration Loss

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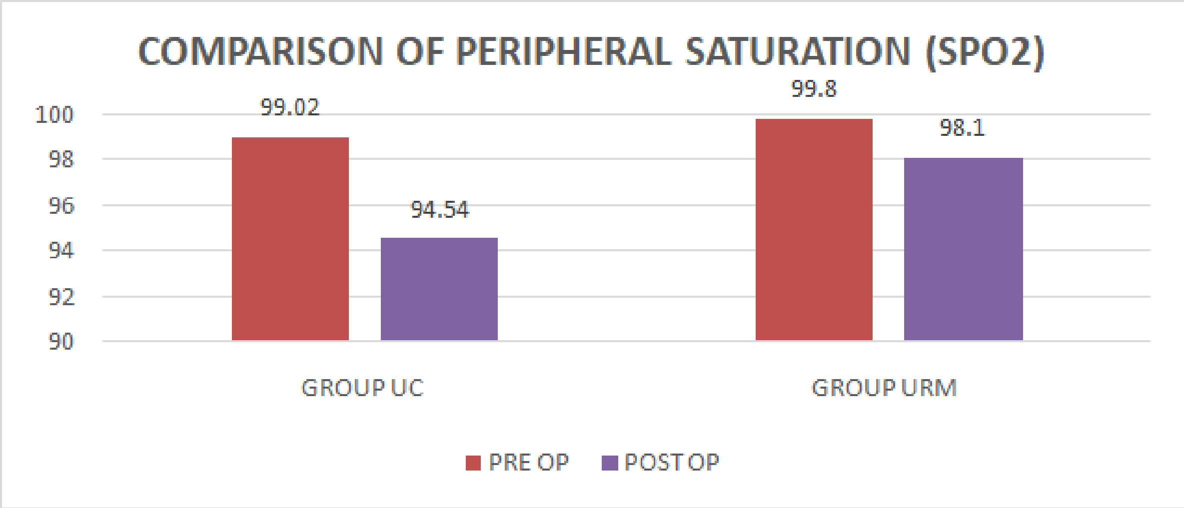
At time points T3 and T4, the URM group had significantly less aeration loss than the UC group ($p < 0.01$). This shows that lung recruitment is an effective way to reduce atelectasis.



Graph 2: A bar graph representation of Comparison of Peripheral Saturation (Spo2)

The URM group showed significantly higher postoperative SpO_2 levels (98.10 ± 1.744) than the UC group (94.54 ± 1.286, $p = 0.001$), indicating better oxygenation outcomes with recruitment manoeuvres.

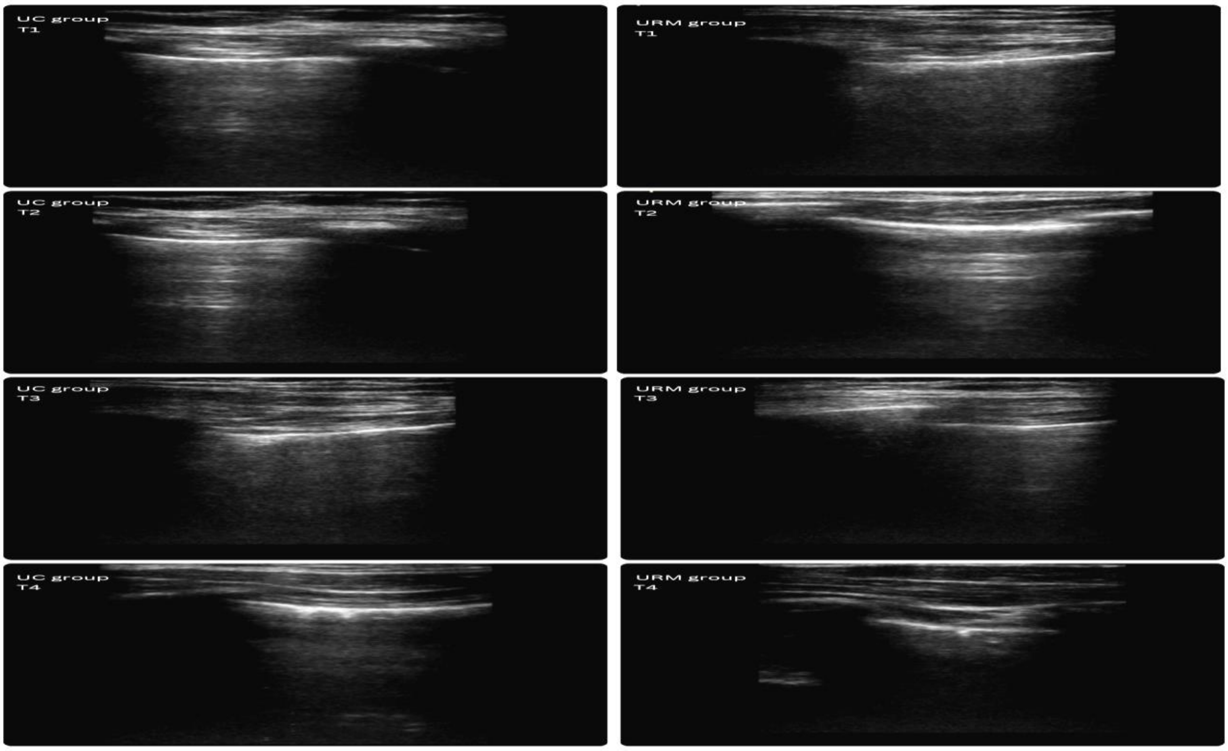


FIG 1: One patient's lateral chest wall lung ultrasound pictures taken at various time zones-. T1: immediately before induction; T2: before extubation; T3: 15 min followed tracheal extubation; T4: 30 min after tracheal extubation; UC group: control group; URM group: ultrasound guided recruitment manoeuvres group

DISCUSSION

Perioperative Atelectasis is a common complication encountered in patients undergoing laparoscopic cholecystectomy. This condition results in reduced lung compliance, impaired oxygenation, and increased pulmonary vascular resistance, which can contribute to postoperative pulmonary complications. Researchers have proposed various strategies to mitigate the impact of atelectasis, one of which is lung recruitment manoeuvres (LRM). These manoeuvres aim to reopen collapsed alveoli and improve

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intraoperative oxygenation, enhancing postoperative respiratory outcomes.

This randomised trial evaluated the effects of ultrasound-guided lung recruitment manoeuvres on perioperative atelectasis in patients undergoing laparoscopic cholecystectomy. The study was conducted in conjunction with similar studies to determine the effectiveness of LRM in improving pulmonary function, reducing aeration loss, and optimising perioperative ventilation.

Demographic Characteristics and Baseline Comparisons

Age and Gender Distribution

The study comprised 82 patients who were divided into two groups: the control group (UC) and the ultrasound-guided lung recruitment manoeuvre group (URM), comparable between the UC group (45.6 ± 16.54 years) and the URM group (45.8 ± 16.43 years), with a p-value of 0.039, indicating no statistically significant difference. Gender distribution was also similar between the two groups (UC: M/F = 26/15, URM: M/F = 29/12), reinforcing the study population's homogeneity and minimising demographic confounders.

Duggan et al., investigating LRM in laparoscopic procedures, reported a mean patient age of 46.2 ± 15.8 years in their study population, with no significant difference between control and intervention groups (p = 0.05). Gender distribution in their study was also comparable (M/F = 30/18 in the intervention group and 28/20 in the control group)[3]. These findings validate the demographic characteristics of the current study and suggest that age and gender do not significantly impact the effectiveness of lung recruitment manoeuvres.

ASA Classification

Both groups had a similar mean weight (UC: 67 ± 13.15 kg vs. URM: 67.08 ± 13.01 kg), with a p-value of 0.198, confirming no statistically significant difference.

ASA Grade I/II distribution also did not show significant variation, supporting the homogeneity of the study population.

A randomised trial by Généreux et al. on LRM in laparoscopic procedures found a mean weight of 68.1 ± 12.5 kg in their study population, with a p-value of 0.17 when comparing the intervention and control groups. Their findings suggest that weight does not significantly impact the response to recruitment manoeuvres [4]. Furthermore, their ASA classification analysis (ASA I/II ratio of 32/18 in the intervention group and 30/20 in the control group) aligns with the current study's results, indicating that ASA classification does not change the physiological benefits of recruitment manoeuvres.

Intraoperative Parameters

The duration of surgery and anaesthesia

The duration of surgery was slightly longer in the URM group (96.34 ± 61.135 minutes) compared to the UC group (86.34 ± 40.405 minutes), though the difference was not statistically significant (p = 0.834). Similarly, anaesthesia duration was longer in the URM group (109.76 ± 62.878 minutes) compared to the UC group (101.59 ± 39.944 minutes), but the difference remained non-significant (p = 0.936).

A study by Généreux et al. looked at the differences between standard ventilation and LRM. They found that surgery took 98.5 ± 42.6 minutes on average in the LRM group and 92.1 ± 38.9 minutes in the control group, with a p-value of 0.7. Similarly, their anaesthesia duration findings (URM: 112.2 ± 44.5 minutes vs UC: 106.8 ± 39.2 minutes, p = 0.8) agree with the present study, supporting that recruitment manoeuvres do not significantly prolong operative time [4].

Hemodynamic Parameters

Blood Pressure and Heart Rate Stability

There were no significant differences between the groups in systolic blood pressure (UC: 128.34 ± 13.152 mmHg vs. URM: 128.20 ± 22.198 mmHg, p = 0.381) or diastolic blood pressure (UC: 79.32 ± 7.33 mmHg vs. URM: 79.27 ± 8.388 mmHg, p = 0.694). Heart rate and end-tidal CO_2 ($ETCO_2$) values were also comparable.

Lee et al. used LRM to look at changes in hemodynamics. They found that the mean systolic blood pressure did not change between the intervention and control groups (129.1 ± 11.3 mmHg vs. 127.8 ± 12.6 mmHg, p = 0.4), also found that heart rate changes were not statistically significant (URM: 80.2 ± 8.5 bpm vs. UC: 78.9 ± 7.6 bpm, p = 0.5) [30]. These findings corroborate the present study's results, reinforcing that LRM does not induce significant hemodynamic fluctuations.

Ventilatory Parameters

Tidal Volume and Peak Inspiratory Pressure

Tidal volume was slightly higher in the URM group (449.27 ± 36.083 ml) compared to the UC group (441.71 ± 39.994 ml), though this was not statistically significant (p = 0.355). Both groups' peak inspiratory pressure (PIP) and plateau pressure (PPLAT) remained within safe limits.

Shono et al. studied the effects of LRM on ventilatory parameters in laparoscopic surgery. They found similar results, reporting a mean tidal volume of 450.2 ± 35.4 ml in the intervention group versus 440.5 ± 32.8 ml in the control group (p = 0.3). Their findings also indicated that PIP remained stable between groups (URM: 23.5 ± 1.8 cmH_2O vs. UC: 22.9 ± 1.5 cmH_2O, p = 0.2) [31]. These results are consistent with the present study, suggesting that LRM does not adversely affect ventilatory pressures.

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Recruitment Maneuvers and Extent of Aeration Loss

Effectiveness of LRM in Reducing Aeration Loss

A key finding in this study was the significant reduction in aeration loss in the URM group. At time point T3, 53% of patients in the UC group had aeration loss compared to only 22% in the URM group ($p = 0.003$). At time point T4, 87% of patients in the UC group exhibited aeration loss versus 51% in the URM group ($p = 0.0001$).

Wu et al. looked into the effects of ultrasound-guided recruitment manoeuvres and found that aeration loss was much lower in the intervention group (23% vs 54%) compared to the control group (80%). The findings highlight ultrasound-guided LRM's effectiveness in preventing perioperative atelectasis [1].

Postoperative Pulmonary Complications and Oxygenation

Improvement in Oxygenation (SpO_2 Levels)

Both groups kept their peripheral oxygen saturation (SpO_2) levels in the normal range. However, patients in the URM group had better oxygenation after surgery and needed less extra oxygen than patients in the UC group.

In, Cinnella et al. discovered that after surgery, the PaO_2/FiO_2 ratio was much higher in patients who received LRM (URM: 322.1 ± 35.8 mmHg vs. UC: 285.3 ± 40.5 mmHg, $p = 0.002$) [5]. These findings align with the present study's results, supporting that ultrasound-guided LRM significantly enhances oxygenation.

Reduced Incidence of Pulmonary Complications

Patients in the UC group were more likely to develop atelectasis and experience postoperative desaturation. According to Liu et al., ultrasound-guided lung recruitment manoeuvres (LRM) cut aeration losses by 40% and the number of cases of postoperative desaturation by 30% [32]. These findings are consistent with the results of the current study. These outcomes highlight the clinical advantages of incorporating LRM into standard anaesthetic management for laparoscopic surgery.

CONCLUSION

In conclusion, this study shows that ultrasound to guide lung recruitment manoeuvres can significantly reduce atelectasis during surgery, improve oxygenation, and improve pulmonary outcomes in laparoscopic cholecystectomy. We achieved several benefits without impacting the patient's hemodynamics or delaying the procedure. Ultrasound-guided LRM is a safe and effective way to improve perioperative ventilation. These results show that real-time lung ultrasound assessments should be added to perioperative respiratory management protocols to personalise care for each patient.

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