**RESEARCH PAPER**

# Ultrasound-Guided Stepwise Lung Recruitment Maneuver Reduces Postoperative Pulmonary Complications in Morbidly Obese Patients Undergoing Laparoscopic Abdominal Surgery: A Randomized Controlled Trial

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**ABSTRACT**
Background: Postoperative pulmonary complications (PPCs) still important in terms of perioperative treatment of major surgeries especially laparoscopic abdominal surgeries. Aim: To estimate the influence of ultrasound-guided stepwise lung recruitment maneuver on reducing PPCs in morbidly obese cases have laparoscopic abdominal surgery. Patients and methods: The research has been a randomized controlled clinical study, which has been performed on 60 adult cases, which have been divided into two groups (age ≥18 years old). The research has been performed at the operating theatres and post-anesthesia care unit in Suez Canal University hospitals. Result: The stepwise lung recruitment maneuver (LRM) group showed significantly lower postoperative lung ultrasound scores and higher $SpO_2$ than the control group (P below 0.05). Postoperative pulmonary complications were significantly diminished in the LRM group (36.67% vs. 63.33%, P = 0.039), with lower rates of bronchospasm, atelectasis, and unplanned ventilation. Heart rate was comparable between groups, while mean arterial blood pressure showed transient differences. Additionally, ARISCAT score showed a significant positive association with postoperative lung ultrasound findings, indicating its predictive value for lung aeration impairment. Conclusion: Lung-protective ventilation and recruitment maneuvers are important during mechanical ventilation, though no standardized protocol exists. The stepwise lung recruitment maneuver is a safe and effective strategy in morbidly obese cases have laparoscopic surgery, reducing PPCs and improving lung aeration even in high ARISCAT risk cases.

**Keywords**: *Ultrasound, Stepwise Lung Recruitment Maneuver, Postoperative Pulmonary Complications.*
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## INTRODUCTION

Postoperative pulmonary complications still important in terms of perioperative management of major surgeries especially laparoscopic abdominal surgeries. PPCs remain an important issue following major operation done under general anesthesia, particularly in elderly cases, morbidly obese cases or patients with lung diseases (1).

Morbidly obese cases exhibit diminished functional residual capacity, which is further exacerbated by supine placement and general anesthesia. Atelectasis is commonly observed during intraoperative breathing in morbidly obese individuals and is likely implicated in the onset of PPCs (2).

Laparoscopic surgery has numerous advantages compared to laparotomy, including a reduced occurrence of PPCs. Nonetheless, the use of carbon dioxide (CO2) for pneumoperitoneum in laparoscopic procedures results in upward displacement of the diaphragm and promotes the development of atelectasis. Pneumoperitoneum results in reduced respiratory compliance and diminished arterial

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oxygenation. These effects may lead to PPCs and prolonged hospital stay (3).

Several ventilator strategies were suggested to improve the postoperative outcome of morbidly obese cases. Lung recruitment maneuvers (LRMs) are considered as lung-protective ventilation strategies which are used to reopen collapsed lungs (4). Stepwise LRM is recently considered safer than other maneuvers as it monitored haemodynamics gradually and help in prevention of early PPCs (5).

LUS is a quick, point of care and radiation free method. It has an excellent diagnostic accuracy for pulmonary edema, atelectasis, pulmonary effusion and pneumonia after major abdominal surgeries compared to gold standard CT. It's confirmed with an accuracy above ninety percent, and are therefore extensively utilized in daily critical care (6).

The goal of this investigation to estimate the influence of ultrasound-guided stepwise lung recruitment maneuver on decreasing PPCs in morbidly obese cases have laparoscopic abdominal operation.

## PATIENTS AND METHODS

The research was a randomized controlled clinical study, which has been conducted on 60 adult cases, which have been divided into two groups (age ≥18 years old). The research has been performed at the operating theatres and post-anesthesia care unit in Suez Canal University hospitals.

### Study Population

Sixty adult patients (≥18 years) of both sexes with body mass index (BMI ≥ forty kg/m²), scheduled for elective laparoscopic abdominal surgeries under general anesthesia, have been enrolled. All cases were at risk for PPCs based on the ARISCAT risk score. Written informed consent has been attained, and ethical approval has been granted.

### Sample Size Justification

The sample size has been calculated applying the following formula

$$n = \left[\frac{Z_{\alpha/2} + Z_{\beta}}{P_1 - P_2}\right]^2 (p_1 q_1 + p_2 q_2)$$ (7).

Where

n = sample size.

P1 = Prevalence of hypoxia in research group = 10% (8).

P2 = Prevalence of hypoxia in the control group = 25% (8).

Zβ = 0.84 (The critical value that separates the lower twenty percent of the Z distribution from the upper eighty percent).

Zα/2 = 1.96 (The critical value that divides the central ninety-five percent of the Z distribution from the five percent in the tail).

So, by calculation, the sample size is equal to 30 individuals per group following the addition of a drop-out proportion of ten percent. Thirty individuals per group were recruited. The final figure for the sample size was 60 in total divided equally between 2 groups.

### Sampling randomization process

Cases have been randomly allocated into two equal groups (num. = 30 each) utilizing a computer-generated randomization table with sealed opaque envelopes:

Recruitment group (R group): received stepwise lung recruitment maneuver

Control group (C group): received conventional ventilation with physiological PEEP

Lung ultrasound (LUS) assessment was performed by trained anesthesiologists blinded to group allocation.

**Inclusion criteria:** Include age ≥ eighteen years old, both sexes will be included, BMI ≥ forty, ASA I and II and elective laparoscopic abdominal (e.g. gastrointestinal, vascular, or gynecological) surgeries under general anesthesia.

**Exclusion criteria:** Included refusal of the patient, emergency surgery for trauma, infection at the chest wall, time of operations less than two hours and patients with preoperative pulmonary comorbidites (Asthmatic, COPD, IPF & lung cancer).

## METHOD

### All patients were subjected to:

All cases have a comprehensive preoperative assessment that involved detailed medical history taking, thorough physical examination, and airway assessment. Routine laboratory examinations were performed for all participants. In addition, patients have been stratified according to the ARISCAT risk score into low, intermediate, and high risk for PPCs.

## INTERVENTION

### Control Group

Cases received volume-controlled ventilation with:

Tidal volume: eight milliliters/kilogram (ideal body weight)

PEEP: five centimeters $H_2O$

### Recruitment Group

Patients received stepwise LRM after pneumoperitoneum using:

Incremental PEEP (2–5 $cmH_2O$ steps).

Tidal volume: six milliliters/kilogram.

Adjustment based on: Driving pressure, oxygen saturation, Lung compliance and hemodynamics

Recruitment was optimized to achieve lung reopening while avoiding overdistension.

**Postoperative management and assessment**

Immediately after extubation, all patients received oxygen via facemask at 6 L/min. Lung ultrasound was performed using an HD11 EX Philips device (3.5–10 MHz probes) at 30 minutes post-extubation and on postoperative days 1, 2, and 3, with the operator blinded to clinical data and group allocation. A standardized six-zone scanning protocol of both lungs was used, and aeration was assessed using four patterns: normal (N), moderate loss (B1), severe loss (B2), and consolidation (C), scored from 0 to 3 to generate a total lung ultrasound score varying from 0 to 36, with recording of consolidated zones. Ultrasound findings included consolidation, PLAPS, alveolar-interstitial syndrome, pneumothorax, pleural effusion, and pericardial effusion, each defined by established sonographic criteria. Vital signs (blood pressure, heart rate, and $SpO_2$) were recorded immediately after recovery and at multiple time points up to 48 hours postoperatively. Early PPCs within the first three days were documented, involving pneumonia, atelectasis, bronchospasm, pulmonary congestion, pneumothorax, pleural effusion, respiratory failure, and need for ventilatory support. Postoperative pain has been managed utilizing patient-controlled analgesia with fentanyl (12 µg/mL) and intravenous paracetamol, with pain assessed utilizing the Numerical Rating Scale up to 48 hours, targeting a score ≤ 3, where 0 represents no pain and the maximum value indicates the worst imaginable pain.

**Ethical Consideration**

The research has been done with no conflict of interest. Ethical approval principles were followed, and written informed consent has been attained from all participants following explaining the research purpose, procedures, and possible side effects in a clear manner. Confidentiality and patient privacy were fully maintained, and data were used only for research purposes. The procedures carried minimal risk and were performed by skilled anesthesiologists under ultrasound guidance. Patients had the right to refuse participation or withdraw at any time without consequences. In case of postoperative complications, appropriate management was provided by the ICU team, and patients had continuous access to the research team. The study aimed to benefit patients through early detection of postoperative pulmonary complications using lung ultrasound, enabling timely management, reduced hospital stay, and faster recovery.

**Statistical Analysis**

Statistical analysis has been done applying SPSS version 26 (IBM Inc., Armonk, NY, United States of America). The normality of information distribution has been assessed utilizing the Shapiro–Wilk test and histograms. Quantitative parametric information is provided as mean ± SD and evaluated utilizing the unpaired Student's t-test, whilst non-parametric information is expressed as interquartile range and median and analyzed applying the Mann–Whitney test. Qualitative parameters have been provided as frequencies and percentages, and comparisons have been made applying the Chi-square test or Fisher's exact test when applicable. Spearman's correlation has been employed to evaluate correlations among non-parametric quantitative parameters. A two-tailed p-value of below 0.05 has been deemed statistically significant.

**RESULT**

Age was significantly diminished in stepwise LRM group than control group (P value =0.012). Sex and BMI were insignificantly different among the studied groups (Table1).

**Table 1:** Demographic data of the examined groups.

| | | Stepwise LRM group (num.=thirty) | Control group (num.=thirty) | P value |
|---|---|---|---|---|
| Age (years) | Mean ± SD | 41.73 ± 8.23 | 48.3 ± 11.26 | 0.012* |
| | Range | 28 - 61 | 36 - 65 | |
| Sex | Male | 11 (36.67%) | 9 (30%) | 0.584 |
| | Female | 19 (63.33%) | 21 (70%) | |
| BMI ($kg/m^2$) | Mean ± SD | 43.35 ± 2.87 | 44 ± 2.08 | 0.325 |
| | Range | 40.9 - 51.9 | 40.8 - 46.9 | |

BMI: body mass index, LRM: lung recruitment maneuver, *: significant as P value ≤ 0.05

Postoperative lung ultrasound at all different time measurements was significantly reduced in stepwise LRM group than control group (P value below 0.001) (Table 2).

**Table 2:** Postoperative lung ultrasound score of the examined groups.

| | Stepwise LRM group (num.=thirty) | Control group (num.=thirty) | P value |
|---|---|---|---|
| Post extubation | 0 (0 - 1) | 3 (2 - 5) | <0.001* |
| Day 1 postoperative | 2 (1 - 3) | 4 (4 - 8) | <0.001* |
| Day 2 postoperative | 2 (1 - 4) | 6 (3 - 7) | <0.001* |
| Day 3 postoperative | 2 (0 - 6) | 7 (5 - 8) | <0.001* |

Data presented as median (IQR).

Postoperative SpO2 at all different time measurements was significantly increased in LRM group than control group (P value below 0.05) (Table 3).

**Table 3:** Postoperative SpO2 (%) of the examined groups.

| | LRM group (num.=30) | Control group (num.=30) | P value |
|---|---|---|---|
| Post extubation | 94.6 ± 1.52 | 92.33 ± 1.37 | <0.001* |
| Day 1 postoperative | 95.03 ± 1.94 | 93.77 ± 1.41 | 0.005* |
| Day 2 postoperative | 95.4 ± 1.69 | 94.03 ± 1.5 | 0.002* |
| Day 3 postoperative | 95.67 ± 1.47 | 94.33 ± 1.58 | 0.001* |

Data presented as mean ± SD, LRM: lung recruitment maneuver, SpO2: Oxygen saturation, *: significant as P value ≤ 0.05

Postoperative MABP at day 1 and 2 was significantly increased in stepwise LRM group than control group (P value below 0.05) while it was insignificantly different between the studied groups post extubation and day 3 postoperative (Table 4).

**Table 4:** Postoperative MABP (mmHg) of the examined groups.

| | Stepwise LRM group (num.=30) | Control group (num.=30) | P value |
|---|---|---|---|
| Post extubation | 85.27 ± 7.31 | 81.47 ± 9.89 | 0.096 |
| Day 1 postoperative | 84.33 ± 9.16 | 76.5 ± 12.66 | 0.008* |
| Day 2 postoperative | 83.07 ± 6.49 | 77.17 ± 9.68 | 0.007* |
| Day 3 postoperative | 81.87 ± 5.84 | 78.2 ± 10.77 | 0.106 |

MABP: mean arterial blood pressure.

Postoperative HR was insignificantly different between the studied groups at all different time measurements (Table 5).

**Table 5:** Postoperative HR (beats/min) of the examined groups.

| | LRM group (num.=thirty) | Control group (num.=thirty) | P value |
|---|---|---|---|
| Post extubation | 84.73 ± 8.52 | 81.17 ± 9.55 | 0.132 |
| Day 1 postoperative | 80.53 ± 8.52 | 78.83 ± 7.7 | 0.421 |
| Day 2 postoperative | 79.1 ± 8.32 | 77.47 ± 8.33 | 0.450 |
| Day 3 postoperative | 78.4 ± 7.77 | 77.57 ± 8.29 | 0.689 |

Data presented as mean ± SD, HR: heart rate.

Total number of cases with PPCs were significantly increased in control group than LRM group (11 (36.67%) vs. 19 (63.33%) respectively (P value =0.039) as bronchospasm, atelectasis, and unplanned ventilation were significantly increased in control group than LRM group (P value =0.042, 0.037, and 0.032 correspondingly) while pneumonia, pulmonary congestion, and pneumothorax were insignificantly different between the examined groups (Table 6).

**Table 6:** PPCs of the studied groups.

| | Stepwise LRM group (num.=thirty) | Control group (num.=thirty) | P value |
|---|---|---|---|
| Pneumonia | 0 (0%) | 1 (3.33%) | 1.000 |
| Bronchospasm | 3 (10%) | 9 (30%) | 0.042* |
| Atelectasis | 9 (30%) | 17 (56.67%) | 0.037* |
| Pulmonary congestion | 2 (6.67%) | 3 (10%) | 1.000 |
| Pneumothorax | 3 (10%) | 6 (20%) | 0.472 |
| Unplanned ventilation | 7 (23.33%) | 15 (50%) | 0.032* |
| No | 19 (63.33%) | 11 (36.67%) | 0.039* |

In the stepwise lung recruitment maneuver (LRM) group, BMI showed a significant positive correlation with lung ultrasound score immediately post-extubation (r = 0.415, p = 0.023), while insignificant association has been observed on postoperative days 1, 2, or 3. In contrast, the ARISCAT score revealed a significant positive correlation with lung ultrasound scores at all-time points, including post-extubation (r = 0.489, p = 0.006), and on postoperative days 1 (r = 0.637, p below 0.001), 2 (r = 0.703, p below 0.001), and 3 (r = 0.548, p = 0.002),

indicating a consistent relation between greater ARISCAT scores and worse postoperative lung aeration. (Table 7).

**Table 7:** Correlation between ARISCAT score and postoperative lung ultrasound of stepwise LRM group

| | BMI | | ARISCAT score | |
|---|---|---|---|---|
| | r | P value | r | P value |
| Post extubation | 0.415 | 0.023* | 0.489 | 0.006* |
| Day 1 postoperative | 0.152 | 0.424 | 0.637 | <0.001* |
| Day 2 postoperative | 0.167 | 0.377 | 0.703 | <0.001* |
| Day 3 postoperative | 0.341 | 0.065 | 0.548 | 0.002* |

r: correlation coefficient, ARISCAT: Assess Respiratory Risk in Surgical Patients in Catalonia.

## DISCUSSION

Timely identification of PPCs may be crucial for care and monitoring, as these cases frequently possess diminished physiological reserves. The interval from surgery to the discovery of PPC is approximately three days utilizing the most prevalent diagnostic methods. Bedside lung ultrasound (LUS), a diagnostic imaging technique with elevated sensitivity and specificity, is being utilized more frequently for the identification of pulmonary disorders (9).

Regarding the incidence of PPCs, total number of cases with PPCs were significantly increased in control group than stepwise LRM group (11 (36.67%) in LRM vs. 19 (63.33%) in control group (P value =0.039).

This result is matched with Zhou L, et al. (2023) who found in eight studies that utilizing PEEP titration through mechanical ventilation significantly diminished PPCs in the random-effect model (RR = 0.54, 95% CI 0.42 to 0.69) with heterogeneity (I2 = 0%) (10).

Regarding postoperative lung ultrasound of the studied groups, the current study shows that Postoperative lung ultrasound at all different time measurements was significantly diminished in stepwise LRM group than control group (P value below 0.001).

This result is in the same line with Liu et al, (11) who found that the incidence of atelectasis was 50.0%, 52.4%, and 42.5% in the PEEP group, Control group, and RM accompanied with PEEP group at the end of operation, correspondingly

About postoperative SpO2 (%) of the studied groups, the current study estimates that Postoperative SpO2 at all different time measurements was significantly increased in LRM group than control group (P value below 0.05).

This result is in agreement with Liu et al. (11)who found that The frequency of postoperative hypoxemia was 15.0%, 27.5%, and 5.0% in the protective group, control group, and recruitment group, (P below 0.017) respectively.

In relation to postoperative MABP (mmHg) of the studied groups, the current study shows that postoperative MABP at day 1 and 2 was significantly increased in LRM group than control group (P value below 0.05) while it was insignificantly different among the studied groups post extubation and day 3 postoperative.

In contrast to Li, Xiang et al. (12), they found that the rate of hypotension through the recruitment maneuver and the dosage of phenylephrine throughout the operation did not differ among the recruitment and control group. Persistent hypotension hasn't been observed in either group.

Regarding postoperative HR (beats/min) of the studied groups the present study reveals that postoperative HR was insignificantly different between the studied groups at all different time measurements.

This result due to that LRM increase the oxygen saturation with limited effect on the heart beats, with change in Postoperative MABP for only 2 days.

Also Aboseif et al. (13) found that HR was insignificantly different among the study groups at all times of the measurements.

Postoperative pulmonary complications incidence in stepwise LRM group was significantly increased in moderate and severe ARISCAT score (P value =0.029) and it was increased in control group in severe ARISCAT score (P value =0.001).

Related the Correlation between ARISCAT score and postoperative lung ultrasound of stepwise LRM group, In the stepwise lung recruitment maneuver (LRM) group, BMI showed a significant positive correlation with lung ultrasound score immediately post-extubation (r = 0.415, p = 0.023), while insignificant association was observed on postoperative days 1, 2, or 3. In contrast, the ARISCAT score revealed a significant positive association with lung ultrasound scores at all-time points, including post-extubation (r = 0.489, p = 0.006), and on postoperative days 1 (r = 0.637, p below 0.001), 2 (r = 0.703, p below 0.001), and 3 (r = 0.548, p = 0.002), indicating a consistent relation between greater ARISCAT scores and worse postoperative lung aeration.

This result is matched with Wu et al. (14), who found that lung ultrasound scores in the ultrasound-guided alveolar recruitment maneuvers (UD group)were significantly lower than those in both the sustained inflation alveolar recruitment man oeuvres (SI group) group and the control group immediately following the end of operation ($7.67 \pm 1.15$ against $9.70 \pm 102$, variance, -2.03 [ninety-five percent confidence interval, -2.77 to -1.29], P below 0.001; $7.67 \pm 1.15$ against $11.73 \pm 1.96$, variance, -4.07 [ninety-five percent confidence interval, -4.81 to -3.33], P below 0.001; correspondingly).

## CONCLUSION

Lung-protective ventilation strategies, including recruitment maneuvers, are essential during mechanical ventilation, although no standardized guidelines currently exist for their use. Stepwise lung recruitment maneuver appears to be an effective and safe strategy in morbidly obese cases have laparoscopic abdominal surgery. It significantly reduces postoperative pulmonary complications and improves lung aeration as evaluated by lung ultrasound, even in cases with high preoperative ARISCAT risk scores.

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