# Ultrasonographic assessment of atelectasis in major upper abdominal surgeries with different ventilatory strategies

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**Article History: Received:** 25.05.2023 **Revised:** 18.06.2023 **Accepted:** 21.06.2023

**ABSTRACT**

**Background:** Many cases undergoing abdominal surgery under the influence of general anesthesia develop atelectasis. Effects of ventilation on lung perioperatively could be easily assessed using ultrasound. **Aim:** this study was conducted to evaluate whether using PEEP with or without recruitment maneuver could reduce perioperative lung atelectasis using ultrasound in major upper abdominal surgeries. **Methods:** 117 individuals who were set to have open upper abdominal surgery were split into three groups; Low PEEP group (4 cm H2O), High PEEP group (10 cm H2O) and High PEEP with recruitment maneuver group [10 cm H2O + RM (30 cm H2O for 30 s) every 30 min]. At six different predetermined time periods, ultrasonography of the lungs was performed. The primary result was a variance in lung ultrasonography (LUS) score amongst the groups preceding emergence. **Results:** LUS score before emergence was considerably lesser in High PEEP with recruitment Maneuver group than other 2 groups (P= 0.02). This difference started to vanish after extubation (P=0.08). PaO2/FiO2 ratio was considerably greater in High PEEP with recruitment Maneuver group than other 2 groups before emergence. No difference between the 3 groups regarding PPCs was found. **Conclusions:** Adding recruitment maneuver to high PEEP during open upper abdominal surgeries caused less atelectasis and loss of lung aeration by the end of surgery as assessed by LUS and more enhancement of P/F ratio than when PEEP was used alone. However, it didn't affect the rate of PPCs.

**Keywords:** Lung ultrasound; PEEP; Recruitment; Open upper abdominal surgery.

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## INTRODUCTION

Post-operative pulmonary complications (PPCs) are correlated with higher rates of mortality and morbidity. Upper abdominal surgeries have the greatest risk among non-thoracic surgeries for development of PPCs [1, 2]. It is believed that perioperative atelectasis is a critical factor to the formation of PPCs leading to long hospital stay and increased mortality [3, 4].

Subjects undergoing upper abdominal surgery are known to develop atelectasis and changes in lung functions [5]. The closer the incision is to the diaphragm, the higher the hazard of atelectasis [6, 7]. General anesthesia has been associated with atelectasis [8 - 11].

Low tidal volume ventilation caused no enhancement in lung function after major abdominal surgeries [12]. However; high airway pressures and excessive lung expansion may cause lung injury [13]. Application of low tidal volume & moderate PEEP levels as a protective lung ventilation was found to reduce PPCs [14, 15].

Pereira et al. [16] found that application of the optimal PEEP decreased severity of postoperative atelectasis. Généreux et al. [17] discovered that PEEP and RM avoided intraoperative aeration loss when assessing the impact of positive end-expiratory pressure/recruitment procedures in comparison with zero end-expiratory pressure on atelectasis while the cases were undergoing surgery.

Computed Tomography (CT) & chest X-ray (CXR) are used widely to detect PPCs [18]. Lung ultrasound has been recently used in detection of PPCs with no exposure to radiation or waste of time [19].

In our study; during open upper abdominal operations, the objective of this investigation was to assess the impact of high end-expiratory pressure with and without a recruitment technique in comparison with low end-expiratory pressure on lung aeration & atelectasis using ultrasonography.

## PATIENTS AND METHODS

This was a single-center, prospective, randomized, and controlled trial that took place in Gastrointestinal Surgery Centre at Mansoura University amongst May 2021 and November 2022. The protocol for the research was approved by the institutional review board (Code number: MD.21.01.412) & it had been submitted at ClinicalTrials.gov (N CT 04872361; date of registration: May 4, 2021). Everyone who participated in the study gave their written consent following receiving appropriate data.

**Participants:** Cases of both sexes with ages varied from 30 to 60 years who were planned for elective open upper abdominal procedures supposed to last more than 2 hours and who had ASA I, II, or III were involved in the study.

Cases who refused participation, had a body mass index greater than 35 kg/m2, had undergone intrathoracic procedures, had a history of severe restrictive or obstructive lung disease, had pulmonary hypertension, pregnant females, and cases who suffered from psychiatric diseases were not allowed to take part in the research.

**Randomization:** Participants were allocated to one of three equal interventional groups by a straightforward randomization process utilizing computer-generated randomization software. The allocation ratio for the participants was 1:1:1. The assignments to the groups were hidden in envelopes that were opaque, numbered consecutively & sealed. Participants were assigned randomly into one of three groups:

- ***Low positive end expiratory pressure and no recruitment maneuver group (Low PEEP group (LP)):*** Cases were ventilated with PEEP of 4 cm H2O.
- ***High Positive end expiratory pressure group (High PEEP group (HP)):*** Patients were ventilated with PEEP of 10 cm H2O.
- ***High Positive end expiratory pressure and recruitment maneuver group (High PEEP/RM group (HP/RM)):*** Cases were ventilated with PEEP of 10 cm H2O, and then RM (30 cm H2O for 30 s) was applied immediately after the second LUS examination and repeated every 30 minutes till emergence.

**Preoperative Management:** Each participant was evaluated by collecting their medical history, doing a physical exam, and laboratory tests, ECHO, chest CT and PFTs. All Patients were fasting for at least 2 hours from clear fluids and 6 hours from solid nutrition. LUS score of time point A was done for all participants and type of surgery was recorded.

**Anesthesia protocol:** After 3 min of pre-oxygenation with 100% oxygen, general anesthesia was induced by utilizing IV propofol at dose of 1.5-2 mg/kg, fentanyl IV 1- 2 µ/kg and atracurium 0.5 mg/kg. Patient was then mechanically ventilated using Datex-Ohmeda ventilator machine in volume-controlled mode with tidal volume 8 ml/kg respiratory rate of 12-16 breaths/min adjusted to obtain an end-tidal carbon dioxide between 30 and 40 mm Hg. PEEP was settled according to patient's envelope. Anesthesia was then maintained using 2.0–3.0% inhaled sevoflurane and 60% air in oxygen mixture. An arterial catheter was inserted and first arterial blood sample was obtained.

All patients received subcostal transversus abdominis plane (TAP) block following the administration of general anesthesia using 20 ml of 0.25 % isobaric bupivacaine for each side of abdominal wall.

After performing neuromuscular reversal with 0.05 mg/kg of neostigmine and 0.02 mg/kg of atropine, all cases were extubated after the end of the surgery. This was done following recording LUS score of time point D and the ABG result.

The duration of the surgery, intraoperative colloids, crystalloids, blood loss and urine output were all recorded.

All patients were transferred to PACU and supplied with oxygen via a simple face mask at 5 L/min. VAS and LUS score were recorded and if VAS was $\geq 4$, rescue postoperative analgesia was provided using 3 mg of morphine and 1000 mg of paracetamol both IV.

**Lung ultrasonography**: LUS images were acquired at a total of 6 predetermined time points: before GA induction (time point A), 5 minutes afterward GA induction (time point B), 5 minutes afterward completion of the 2nd ultrasound scan which is immediately after first RM in the high PEEP/RM group and 5 minutes following 2nd ultrasound scan in the other 2 groups (time point C), prior to emergence (time point D), 15 minutes following arrival at PACU (time point E), and immediately before discharge from PACU (time point F).

The GE LOGIQ e portable ultrasound equipment equipped with a curvilinear 2-5 MHz transducer was utilized for the imaging of the lung utilizing ultrasound. The front, lateral, and posterior zones of the thorax (which were separated by the anterior and posterior axillary lines) were each split into upper and lower sections for the right and left lungs, making the total number of quadrants in the thorax 12. A scan was performed on the intercostal spaces of each of those locations, and a score was recorded for the area that had the highest pathologic findings.

A grading system was utilized, and a score between 0 and 3 was awarded to each quadrant. A score of 0 indicated normal lung sliding with less than three single B lines, a score of 1 indicated three or more single B lines, a score of 2 indicated coalescent B lines, and a score of 3 indicated consolidated lung. After that, the LUS score, which ranges from 0 to 36, was arrived at by adding together the results of each of the 12 quadrants **(Figure 1, 2, 3).**

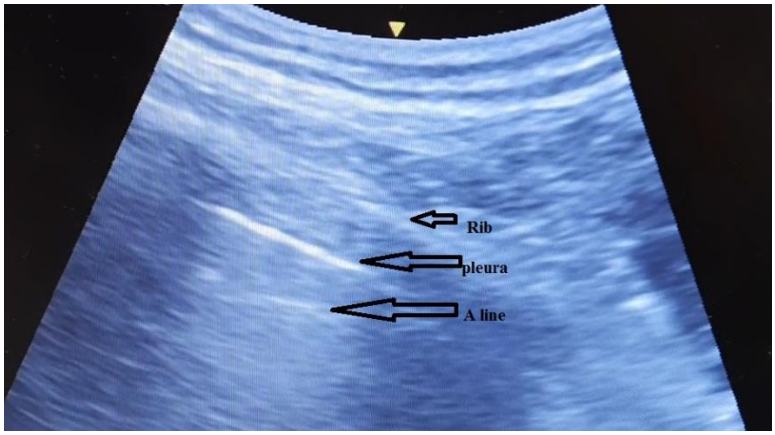


**Figure 1:** Ultrasound scanning of normal lung region.

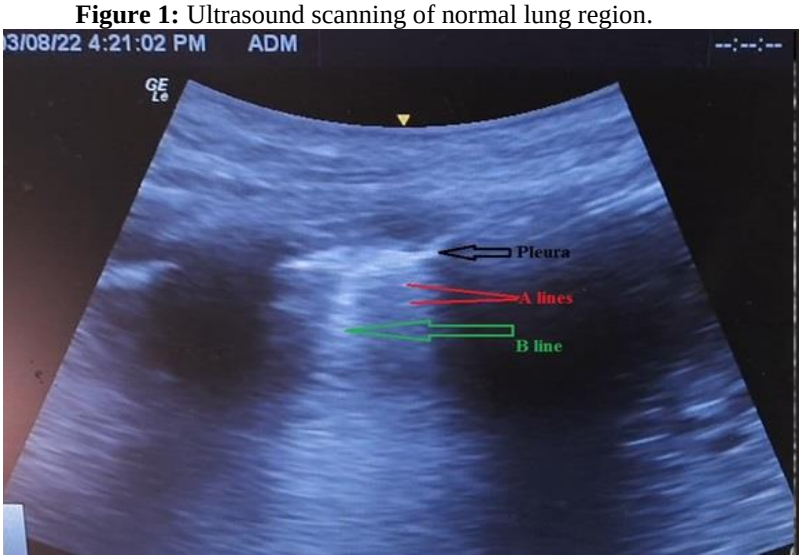


**Figure 2:** Ultrasound scanning showing B line.

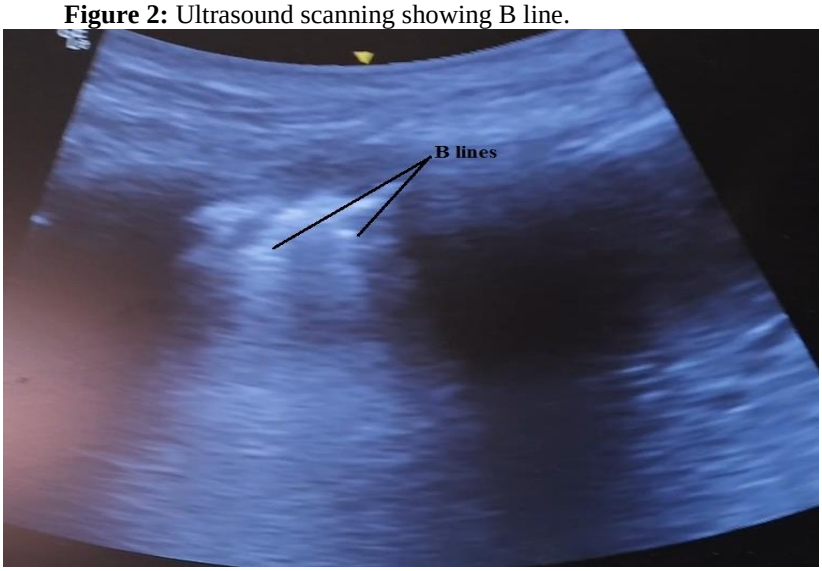


**Figure 3:** Ultrasound image showing multiple and coalescent B lines**.**

**Study outcomes:**

***The primary outcome:*** LUS score between groups at the end of surgery (just before emergence) at time point D as a lower score indicated better lung aeration.

***The secondary outcomes:*** LUS score between groups at time point B, C, E and F. Rate of heartbeat, mean arterial blood pressure, and oxygen saturation at time points A, B, C, D, E, and F respectively. ETCO2, Peak inspiratory pressure (PIP) at time point B, C and D (PaCO2), PaO2/FiO2 at time point B, D and F. PPCs within the first five postoperative days (atelectasis, pneumothorax, pulmonary collapse, pneumonia, acute respiratory distress syndrome (ARDS), pleural effusion, or pulmonary aspiration).

**Statistical analysis:** For the purpose of doing statistical analysis on the data that was gathered, IBM's SPSS statistics (Statistical Package for the Social Sciences) for windows (version 27) was utilized. So as to evaluate whether or not the data have a normal distribution, the Shapiro-Wilk test was carried out. The variables with properly distributed continuous data were described as the mean standard deviation, whereas the variables with abnormally distributed continuous data and categorical data were reported as the median range or the number % (depending on the context). Both the Kruskal Wallis test and the one-way analysis of variance with post-hoc testing were utilized, depending on whether the continuous data were regularly or abnormally distributed. The Chi-square test was utilized for the analysis of categorical data through the usage of the crosstabs function. If the probability value, or P value, was less than 0.05, then the statistical significance was high.

**Sample size calculation:** We had performed a pilot research on 15 patients. The null hypotheses was taken to mean that there was no discernible distinction amongst any of the groups in regards to the lung US score at time point D. lung US score at time point D was 7.8 in Low PEEP group, 7.6 in High PEEP group and 6. 6 in High PEEP/RM group with a 1.25 standard deviation of the data. Using an F test with a significance level (α or the likelihood of rejecting the null hypothesis when it is true) of 5%, the proposed research required a sample size of 31 cases in each group to reach 95percent power. The researchers anticipated that 8 cases would drop out of the study, so they enrolled 39 individuals in each group for a total of 117.

## RESULTS

From May 2021, to November 2022, 117 patients were randomized into Low PEEP (LP) group (n=39), High PEEP (HP) group (n=39), High PEEP/RM (HP/RM) group (n=39). 2 patients were excluded from final analysis due to termination of surgery before 2 hours; one patient in High PEEP group and the other in High PEEP/RM group. **(Figure 4)**

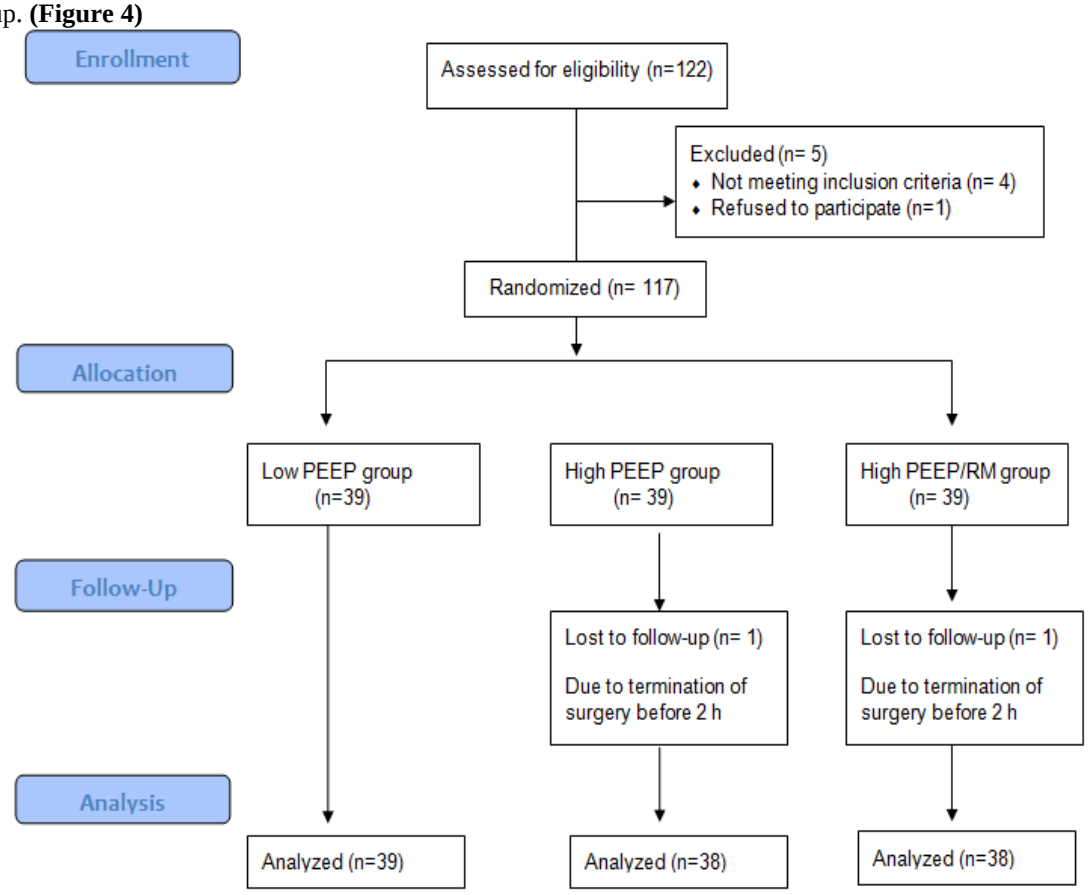


**Figure (4):** CONSORT Flow diagram.

There were no significant variations amongst the three groups regarding gender, age, BMI, smoking status, or PFTs, as reported in table (1).

There was no significant difference ($p > 0.05$) in the operative data amongst the three groups. The average number of minutes spent in surgery was 254 for the LP group, 249 for the HP group, and 250 for the HP/RM group.

The 3 groups also showed no significant difference as regard intraoperative volume of crystalloids, colloids, blood loss and urine output. Median of post-operative visual analogue score was

3 for the three study groups with different statistically non-significant ranges.

**Table (1):** Demographic and perioperative data

| | Group LP N=39 | Group HP N=38 | Group HP/RM N=38 | P value |
|---|---|---|---|---|
| **Age (Y)** | 50.72±8.7 | 51.4±10.28 | 49.9±8.34 | 0.4 |
| **Sex (F/M)** | | | | 0.8 |
| -Female | 23 (59%) | 20 (52.6%) | 22 (57.9%) | |
| -male | 16 (41%) | 18 (47.4%) | 16 (42.1%) | |
| **BMI (KG/m2)** | 28.23±2.88 | 29.4±3.12 | 29.2±2.76 | 0.2 |
| **ASA** | 2 (1-3) | 2 (1-3) | 2 (1-3) | 0.2 |
| **Smoking (y/n)** | 12/27 (30.8%/69.2%) | 12/26 (31.6%/68.4%) | 8/30 (21.1%/78.9%) | 0.5 |
| **PFT** | | | | 0.9 |
| -Normal | 30 (76.9%) | 32 (84.2%) | 30 (78.9%) | |
| -Restrictive | 8 (20.5%) | 5 (13.2%) | 6 (15.8%) | |
| -Obstructive | 1 (2.6%) | 1 (2.6%) | 2 (5.3%) | |
| **Duration(min)** | 253.6±62.1 | 248.7±71.2 | 250.3±76.61 | 0.9 |
| **Operation** | | | | 0.6 |
| -Hepatic | 13 (33.3%) | 15 (39.5%) | 9 (23.7%) | |
| -Pancreatic | 19 (48.7%) | 13 (34.2%) | 18 (47.4%) | |
| -Gastric | 7 (17.9%) | 9 (23.7%) | 10 (26.3%) | |
| -spleen | 0 (0%) | 1 (2.6%) | 1 (2.6%) | |
| **CRYSTALLOIDS** | 3123.08 ±803.761 | 3036.84 ±797.096 | 2984.21 ±701.167 | 0.7 |
| **COLLOIDS** | 0 (0-1000) | 0 (0-1000) | 0 (0-1250) | 0.9 |
| **BLOOD LOSS** | 543.59 ± 166.299 | 519.74± 171.456 | 513.16± 216.447 | 0.8 |
| **UOP** | 820.51± 371.469 | 722.37± 253.542 | 722.37± 316.377 | 0.3 |
| **VAS** | 3 (1-7) | 3 (1-8) | 3 (1-7) | 0.9 |

The medians of lung ultrasound score are expressed in table (2). They were found to be similar before general anesthesia induction (time point A). After the induction, there was a decline in the lung aeration of all three groups that were evaluated at time point B.

The main result of this research was that the lung ultrasonography score preceding emergence (time point D) was found to be significantly less in the group HP/RM than in the other 2 groups, with a P value of 0.02. **(Figure 5)**

Following arriving to the PACU, such difference could no longer be seen either 15 minutes or 1 hour later (time point E and F).

**Table (2):** Lung ultrasound scoring

| | Group LP N=39 | Group HP N=38 | Group HP/RM N=38 | P value |
|---|---|---|---|---|
| **LUS A** | 2 (0-4) | 1.5 (0-3) | 1 (0-3) | 0.4 |
| **LUS B** | 3 (1-7) | 3.5 (1-7) | 3.5 (1-7) | 0.2 |
| **LUS C** | 3 (0-7) | 2.5 (0-6) | 2 (0-6) | 0.7 |
| **LUS D** | 5 (1-10) | 6 (3-9) | 5 (2-7) *ł | 0.02 |
| **LUS E** | 4 (1-8) | 5 (1-9) | 4 (1-7) | 0.08 |
| **LUS F** | 4 (1-8) | 4.5 (2-10) | 4 (0-8) | 0.1 |

* means that group High PEEP/RM is significant to group High PEEP

ł means that group High PEEP/RM is significant to group Low PEEP

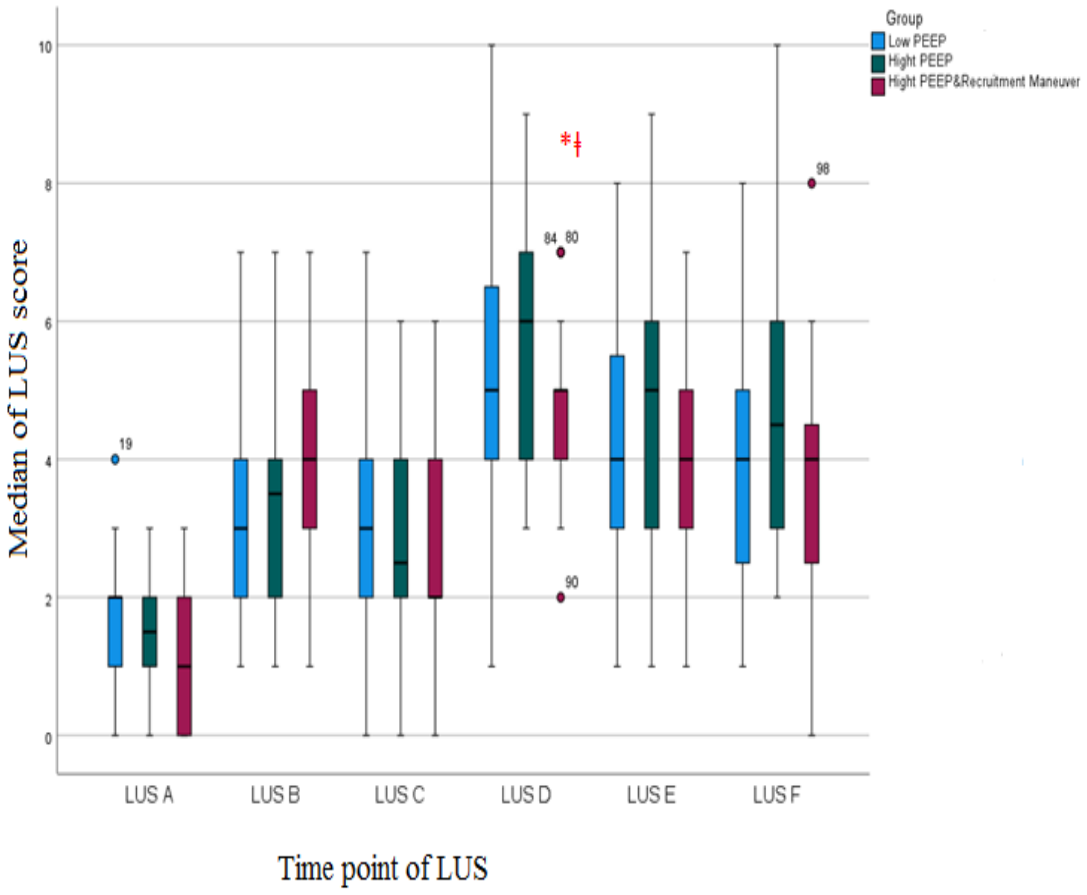


**Figure (5):** Box Plot of lung ultrasound score difference between groups.

No statistically substantial variance were noticed amongst the 3 groups concerning heart rate, mean arterial pressure & Spo2 at time points A, B, C, D, E and F.

Regarding arterial blood gases as part of secondary outcomes, P/F ratio was significantly higher at time point D in group HP/RM with mean 499 than both LP and HP groups with means 435 and 475 respectively. This significance was no longer found after 1 h at the PACU (time point F). Paco2 showed no substantial variance among the 3 study groups. (Table 3)

**Table (3):** Arterial blood gases

| | Group LP N=39 | Group HP N=38 | Group HP/RM N=38 | P value |
|---|---|---|---|---|
| **P/F B** | 469.5±78.87 | 437.6±67.79 | 439.4±146.07 | 0. 2 |
| **P/F D** | 434.8 ±48.34 | 475±122.41 | 499.2±95.69*ł | 0.02 |
| **P/F F** | 441.2±73.24 | 417.5±77.45 | 455.3±101.85 | 0.6 |
| **PaCO2 B** | 34 (29- 42) | 34.5 (29-38) | 32 (28-38) | 0.2 |
| **PaCO2 D** | 34 (29-40) | 35 (29-39) | 35 (31-39) | 0.4 |
| **PaCO2 F** | 38 (32-45) | 35 (29-40) | 38 (32-45) | 0.1 |

Before emergence (time point D), PIP in HP/RM group was considerably greater than group LP with P value 0.002. Nevertheless, at time point C it was higher in groups HP and HP/RM than group LP. (Table 4)

**Table (4):** Peak inspiratory pressure

| | Group LP N=39 | Group HP N=38 | Group HP/RM N=38 | P value |
|---|---|---|---|---|
| **PIP B** | 16 (12-20) | 17 (13-23) | 17 (13-21) | 0.1 |
| **PIP C** | 18 (14-21) | 20 (15-24)π | 20 (15-25) ł | <0.001 |
| **PIP D** | 18 (13-22) | 18 (13-23) | 19 (15-23) ł | 0.002 |

**PIP:** Peak Inspiratory Pressure
π means that group High PEEP is significant to group Low PEEP
ł means that group High PEEP/RM is significant to group Low PEEP

No PPCs were detected in 66.7% of cases of group LP, 73.7% of cases of group HP and 81.6% of cases of group HP/RM. Incidence of lung atelectasis in LP, HP and HP/RM groups was 7.7%, 7.9% and 2.6% respectively. It was 15.4%, 13.2% and 13.2% as regard pleural effusion and 7.7%, 2.6% and 2.6% as regard pneumonia for the same groups.

Only one case developed pulmonary embolism and one case developed pulmonary edema in the study respectively in groups HP and LP. The previous data were found to be non-significant between the three study groups. (Table 5).

**Table (5):** Incidence of post-operative pulmonary complications

| | **Group LP N=39** | **Group HP N=38** | **Group HP/RM N=38** | **P value** |
|---|---|---|---|---|
| **PPC** | | | | 0.7 |
| • No PPC | 26 (66.7%) | 28 (73.7%) | 31 (81.6%) | |
| • atelectasis | 3 (7.7%) | 3 (7.9%) | 1 (2.6%) | |
| • Pleural effusion | 6 (15.4%) | 5 (13.2%) | 5 (13.2%) | |
| • pneumonia | 3 (7.7%) | 1 (2.6%) | 1 (2.6%) | |
| • pulmonary embolism | 0 (0%) | 1 (2.6) | 0 (0%) | |
| • pulmonary edema | 1 (2.6%) | 0 (0%) | 0 (0%) | |

**DISCUSSION:**

This study showed that atelectasis and loss of lung aeration during open upper abdominal surgeries as assessed by ultrasonography were significantly lesser when using high end-expiratory pressure combined with recruitment maneuver than when high end-expiratory pressure alone or low end-expiratory pressure were used as ventilatory strategies. That was proved by lower lung ultrasound score and higher P/F ratio at the end of surgery.

Several studies confirmed that intra operative atelectasis and loss of lung aeration increased gradually throughout general anesthesia time and started to decrease post extubation that was significantly lowered when high PEEP combined with recruitment maneuver was used [17, 20, 21, 22].

In a trial that was quite similar to this one, Généreux et al. demonstrated that combination of PEEP and RM dramatically enhanced lung aeration in comparison to ZEEP without RM, as determined by structured lung ultrasonography, in females who were undergoing gynecological laparotomy operations. This was the case in cases who were receiving RM. Nevertheless, not long after the endotracheal tube was removed, this substantial distinction was no longer seen [17].

Recently in 2022, Liu et al. also proved in their study revealed cases having laparoscopic gynecological surgery benefited more from the use of ultrasound-guided recruitment techniques in conjunction with PEEP than from the use of PEEP alone & that this benefit was lost within 24 hrs following the completion of operation [21].

Although in our study there was still a noticeable but statistically non-significant difference in favor of group HP/RM as regard LUS at time point E, in a study done by Liu et al. it persisted to be significant 15 min after patients' arrival to PACU which may be related to different method of recruitment When atelectasis was observed via ultrasound during and after surgery, the researchers followed a similar procedure, recruiting the lungs through placing the probe in the atelectasis area and increasing airway pressure by 5 cmH2O increments until the collapsed area disappeared on ultrasound. After 40 seconds, the final pressure was held steady at a maximum of 40 cmH2O in the airway [21].

3 Studies have showed that using recruitment maneuvers in different ways during anesthesia resulted in significantly higher P/F ratio than using PEEP alone in different values. This significance gradually faded shortly after extubation which copes with the results of this current study [23 - 25].

Généreux et al. in their study concluded the same result of significant difference as regard P/F ratio before extubation but unexpectedly showed moreover significant difference shortly after extubation in which patients of group Zero PEEP had better P/F ratio than those of group high PEEP/RM that might be correlated to the fact that The PEEP/RM group had a longer length of unaided spontaneous breathing at the time of awakening than the other groups did that caused de-recruiting and loss of lung aeration [17].

In line with the previous last finding, Liu et al. in their research revealed that adding recruitment maneuver to PEEP OF 6 cmH2O caused no significant difference over using the same PEEP alone as regard SPO2 [21].

Similar to previous studies, this research revealed no substantial variance regarding ETCO2 and PaCO2 between the 3 studied groups [17, 25].

In regards to hemodynamics, this study agrees with the study performed by Bluth et al. [26] that showed no substantial variance amongst low PEEP group and high peep with recruitment maneuver group as regard heart rate, mean arterial blood pressure, intraoperative fluids, need for blood transfusion and urine output except for heart rate at

the last hour of operation which was found to be lower in the recruitment group.

In contrast to present research, MAP in the study done by Généreux et al. was found to be considerably greater in the recruitment group at time point E. This contrary may be contributed to different factors other than ventilation strategy like type of surgery (gynecological surgeries), nerve block applied for pain management (epidural analgesia), position of the patients (trendlenburg) and different population [(17)].

As minimizing atelectasis in the postoperative period beside intraoperative period rather than intraoperative only is the mechanism believed to decrease PPCs, and as there was no substantial variance amongst the three groups of the current study as regard atelectasis postoperatively so unsurprisingly there was no substantial variance as regard PPCs amongst the researched groups [(27)].

Many studies handling the repercussions of using intraoperative PEEP with or without recruitment maneuver on the development of PPCs showed that there was no preference of a ventilatory technique of them over the other the same as proved in this study [(24 - 29)].

Not many studies correlated intraoperative ventilator strategies with post-operative pain although it is mandatory to exclude pain as a cause of substantial respiratory disturbance and post-operative vital signs changes or as a result of application of recruitment maneuver.

In this study as patients of the three studied groups received the same protocol for pain management (intraoperative subcostal TAP block and postoperative morphine and paracetamol), there was no significant difference as regard VAS score. This was proved also in 2 studies [(17, 21)].

Effect of application of high PEEP with or without recruitment maneuver on peak inspiratory pressure (PIP) after surgery and prior to extubation is highly controversial between studies. Similar to this study, applying intraoperative recruitment in group of HP/RM during open abdominal surgeries resulted in significantly higher PIP than not applying it in group of LP [(15, 24, 26, 29)].

On the other hand there was no difference as regard the PIP in the research of Généreux et al. that was carried out in open gynecological surgeries which required trendlenburg position of patients that might have been the cause of elevated PIP in all patients [(17)].

In this study, it was noticed that there was significant difference amongst group of HP and group of LP as regard PIP after the third lung ultrasound scanning which can't be correlated with other studies and also between group of HP/RM and group of LP as proved by Bluth et al. [(26)]. This difference could be theoretically attributed to the alveolar over distention caused by using high PEEP and alveolar recruitment.

## CONCLUSION

Adding recruitment maneuver to high PEEP as a ventilatory strategy during open upper abdominal surgeries caused less atelectasis and loss of lung aeration by the end of surgery as assessed by lung ultrasound and more enhancement of P/F ratio than when PEEP was used alone. However, it didn't affect the frequency of PPCs.

## LIMITATIONS

This research has a number of limitations. First, it is a single center study. Second, the sample size is relatively small (117 subjects) and exclusion of morbidly obese patients. Third, we didn't perform the ultrasound examination to assess and follow up subjects for hours or days afterward surgery. Fourth, no further postoperative detection of atelectasis with CT was done.

**Funding:** No funding

**Conflict of Interest:** no conflict of interest.

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