Title Page

Effect of Different Extubation Strategies on Atelectasis in Older Adults Elderly Patients after Major Abdominal Surgeries: A Prospective Randomised Controlled Trial

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**ABSTRACT**

**Introduction:** Older patients are particularly vulnerable to age-related respiratory changes. This prospective randomized controlled trial studied the effects of high and low fractions of inspired oxygen (FiO₂) with the recruitment maneuver (RM) during extubation on lung atelectasis post-operatively in older patients undergoing major abdominal surgery.

**Methods:** We randomized a total of 132 patients aged >60 years who underwent both elective and emergency major abdominal surgeries and met the inclusion criteria into three groups (H, HR, and LR) using computer-generated block randomization. Group H received high FiO₂ (1), Group HR received high FiO₂ (1) with RM followed by a positive end-expiratory pressure of 5 cm H₂O, and Group LR received low FiO₂ (0.4) with RM followed by a positive end-expiratory pressure of 5 cm H₂O 10 min before extubation. Oxygenation and atelectasis were measured using the arterial partial pressure of oxygen (PaO₂)/FiO₂ ratios and lung ultrasound score. Postoperative pulmonary complications were recorded up to 24 h postoperatively.

**Results:** The mean PaO₂/FiO₂ at 30 min post-extubation was significantly higher in Groups LR and HR compared to that in Group H (390.71 ± 29.55, 381.97 ± 24.97, and 355.37 ± 31.7, p <0.001). In the immediate postoperative period, the median lung ultrasound score was higher in Group H than that in Groups LR and HR (6 [5–7]), 3 [3–5], and 3.5 [2.25–4.75], p <0.001). The incidence of oxygen desaturation and oxygen requirements was higher in Group H during the postoperative period.

**Conclusion:** The RM before extubation is beneficial in reducing atelectasis and postoperative pulmonary complications, irrespective of the FiO₂ concentration used in older adults undergoing major abdominal surgeries.

**Trial registration NUMBER:** Ref. No. CTRI/2022/04/042115

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**Glossary of Terms**

FiO₂: fraction of inspired oxygen

LUS: lung ultrasound

LUSS: lung ultrasound score

PaO₂: arterial partial pressure of oxygen

PEEP: positive end-expiratory pressure

PPCs: postoperative pulmonary complications

RM: recruitment maneuver
INTRODUCTION

Older patients have altered respiratory physiology owing to age-related changes and decreased physical activity, leading to decreased physical and pulmonary reserves. In this population, the lungs undergo changes with respect to respiratory mechanics, gas exchange, and immune function. Decreased immunity, upper airway tone, and ineffective cough reflexes increase the risk of postoperative pulmonary complications (PPCs) \(^1,2\). At the molecular level, alterations in collagen levels lead to alveolar duct dilation and the loss of lung recoil, decreased tidal volume, forced expiratory volume in 1 s, and decreased forced vital capacity, along with increased residual volume and respiratory rate \(^3\). These patients are at increased risk of developing postoperative lung complications after major abdominal surgeries under general anesthesia, as anesthetic drugs can cause decreased respiratory muscle tone and abolish the sigh reflex \(^4\). Open upper abdominal surgeries impact ventilation, as they can affect diaphragm function and cause reduced motility, thereby decreasing ventilation in dependent zones and atelectasis. During major laparoscopic abdominal surgeries, the creation of a pneumoperitoneum causes decreased compliance. Additionally, positioning during surgery, such as in the Trendelenburg position, with increased intra-abdominal pressure due to artificial pneumoperitoneum, exacerbates the problem by causing lung base atelectasis. Intraoperatively, this problem leads to decreased oxygenation, which can be overcome by using a high fraction of inspired oxygen; however, this in turn can lead to absorption atelectasis. Absorption atelectasis occurs due to the rapid movement of oxygen into the capillaries, which is not compensated for by the diffusion of gases back from the capillaries into the alveoli at the same rate \(^5\).

A high fraction of inspired oxygen is routinely administered during extubation. However, this may aggravate existing atelectasis and increase the risk of postoperative lung complications in older patients. The recruitment maneuver (RM) involves the use of positive inspiratory airway pressure to recruit collapsed alveoli to increase available alveolar units participating in gas exchange, decrease intrapulmonary shunts, increase lung compliance, and improve oxygenation \(^6\). Ning et al. reported that RM is safe in older patients and significantly improves oxygenation after major surgeries \(^7\). Several
studies have compared the effects of high and low fractions of inspired oxygen (FiO₂) in different age groups and non-abdominal surgeries; however, few studies have compared high and low FiO₂ with RM followed by the application of positive end-expiratory pressure (PEEP) in older patients undergoing abdominal surgery⁸⁻¹⁰.

In this study, we hypothesized that a low FiO₂ (0.4) during extubation with RM would decrease the incidence of lung atelectasis postoperatively in older patients undergoing major abdominal surgeries as compared to a high FiO₂ (1) with or without RM.
METHODS

After obtaining institutional ethics committee approval (AIIMS/IEC/2021/3738) on August 31, 2021, and registering the trial in the Clinical Trials Registry-India (CTRI, ref. no. CTRI/2022/04/042115, date of registration April 25, 2022), written informed consent was obtained from all patients who fulfilled the inclusion criteria. We conducted this study at a single academic tertiary care hospital between April 2022 and April 2023 and adhered to the applicable Consolidated Standards of Reporting Trials (CONSORT) guidelines. The trial was registered before patient enrollment. This study included patients aged ≥60 years who underwent elective and emergency major abdominal surgery. Major abdominal surgery included procedures lasting >2 h or with anticipated blood loss >500 mL. We excluded patients with body mass index (BMI) >30 kg/m², severe cardiopulmonary disease, hemodynamic instability, and cerebrovascular disease.

We allocated the patients randomly at a ratio of 1:1:1 into three treatment groups—H, high FiO₂ (1) alone; HR, high FiO₂, RM, and PEEP; and LR, low FiO₂ (0.4), RM, and PEEP—based on computergenerated block randomization. The use of sealed, opaque envelopes allowed the concealment of allocations handed to the respective treating anesthesiologist. All patients fasted overnight and received oral alprazolam (0.25 mg) the night before surgery. In the operating theater, the patients were monitored using a three-lead electrocardiogram (ECG), non-invasive blood pressure (NIBP) measurement, and pulse oximetry. Electrodes for Bispectral (BIS) and a train of four (TOF) monitoring were attached (Drager Primus Anesthesia Device Monitor, Drager Medical Systems, Inc., Denver, MA, USA). A standard anesthesia protocol was followed for all patients. After 3 min of preoxygenation with 100% oxygen, general anesthesia was induced with fentanyl (2 µg/kg), propofol (2–3 mg/kg), and atracurium (0.5 mg/kg). Anesthesia was maintained using isoflurane, 40% oxygen in the air, and atracurium boluses. The lungs were ventilated using volume-controlled ventilation with
a tidal volume of 6–8 mL/kg ideal body weight (IBW), a respiratory rate of 12–14 breaths/min, and a PEEP of 5 cm H₂O. The tidal volume and respiratory rates were adjusted to maintain an end-tidal carbon dioxide concentration of 35–40 mmHg and an oxygen saturation of 95–100%. In laparoscopic surgery, CO₂ was insufflated into the peritoneal cavity until the intra-abdominal pressure reached 12 mmHg. During surgery, all patients received 5–8 mL kg⁻¹ h⁻¹ Ringer’s lactate. An epidural catheter was inserted before induction in all patients, and 0.2% ropivacaine with fentanyl (2 µg/cc) was administered at a rate of 5 mL/h and continued postoperatively. Fentanyl (1 µg/kg) was administered intraoperatively for analgesia when required at the discretion of the treating anesthesiologists. Postoperatively, all patients received a 0.2% ropivacaine infusion through an epidural catheter for postoperative analgesia. Paracetamol (1 g) was administered intravenously as a rescue analgesic for breakthrough pain to maintain a visual analog score (VAS) <4.

Ten minutes before extubation, FiO₂ in Group H was increased to 1 (control group). Group LR patients received RM with 40 cm H₂O for 40 s, followed by PEEP (5 cm H₂O) and low FiO₂ (0.4). Group HR patients received RM with 40 cm H₂O for 40 s, followed by PEEP (5 cm H₂O) and high FiO₂ (1) (Figure 1).

At the end of surgery, the neuromuscular block was reversed with neostigmine (0.05 mg/kg) and glycopyrrolate (0.01 mg/kg). The trachea was extubated when the patient was fully awake without applying any positive pressure. Arterial blood gas samples were obtained at baseline before anesthesia induction (T1), 10 min after anesthesia induction (T2), 30 min after extubation (T3), and 6 h postoperatively (T4). Lung ultrasonography (USG) was performed preoperatively, 30 min after extubation, and 24 h after surgery. Lung ultrasound (LUS) imaging was performed by two trained anesthesiologists with >3 years of experience in lung USG using a 5–9 MHz linear probe (SonoSite M-Turbo, Bothell, WA, USA). Both anesthesiologists performing the USG and the patients were blinded to the allotment. The modified lung ultrasound score (LUSS) system suggested by Monastesse et al. was used for assessment. The thorax was divided into 12 quadrants: the anterior,
lateral, and posterior zones (separated by the anterior and posterior axillary lines), each divided into the upper and lower portions of the right and left lungs. The aeration loss was assessed by calculating the LUSS. Each of the 12 quadrants was assigned a score of 0–3 according to a grading system. The LUSS (0–36) was then calculated by adding the 12 individual quadrant scores, with higher scores indicating more severe aeration loss. Scoring was defined as follows: 0, normal lung with sliding pleura and equidistant A lines parallel to the smooth pleural line; 1, moderate aeration loss and no less than three scattered B lines derived from the pleural line; 2, severe aeration loss and an irregular pleural line with coalescent B lines; and 3, complete aeration loss and a tissue-like pattern or subpleural consolidation.

The treating anesthesiologists collected demographic and anthropometric data preoperatively. pH, PaO₂, PaO₂/FiO₂, PCO₂, HCO₃⁻, and lactate values were obtained using arterial blood gas (ABG) analysis at the specified time points. Other relevant data, including the ventilatory setting and surgical position, were obtained from anesthesia charts. We measured the primary outcomes in terms of postoperative oxygenation and atelectasis using the ABG and LUSS. The LUSS was recorded at specified time points by the anesthesiologists performing the USG. We recorded the secondary outcomes in terms of postoperative desaturation, oxygen requirement, pneumonia, and ICU admission during the hospital stay.

Statistical analysis: As reported by Kim et al. ¹² the LUSS in the high FiO₂ group was 12.5 ± 1.73. To estimate a 10% decrease in the low FiO₂ group, we calculated a sample size of 44 per group at a 95% confidence interval (CI), 80% power (adjusted for three groups), and 10% contingency for dropouts. The data were entered into MS Excel and analyzed using IBM SPSS Statistics for Windows, version 20.0. We assessed the normality of the data using the Kolmogorov–Smirnov test. Continuous parametric data were reported as means and standard deviations, while non-parametric data were reported as medians. Categorical data are reported as percentages. We compared categorical data between two or more groups using the chi-square test and continuous data between more than two
groups using one-way analysis of variance (ANOVA). We applied post-hoc Tukey’s test to assess the statistical significance of differences between the two groups. A comparison of continuous data across a one-time interval was performed using a paired t-test, and a comparison across multiple time intervals was performed using a repeated-measures ANOVA. Statistical significance was set to p<0.05.

RESULTS

We assessed a total of 132 patients for eligibility for inclusion in this study. Among these, six patients were excluded from the analysis because they were not extubated and were transferred to the ICU. Thus, we analyzed 126 patients (Figure 2). The baseline characteristics are summarized in Table 1. The baseline patient characteristics were comparable among the three groups.

Regarding the primary outcome, the PaO₂/FiO₂ decreased in all groups from baseline until 6 h postoperatively. The PaO₂/FiO₂ differed significantly between Group H and Groups LR and HR 30 min after extubation and 6 h after the procedure, with higher ratios in Groups LR and HR (Table 2, Figure 3), with no statistically significant difference between Groups LR and HR.

In the postoperative period, the median LUSS was highest in Group H (median 6, interquartile range [IQR] 5–7) and differed significantly from the median LUSS values for all areas observed in Groups LR and HR (median 3, IQR 3–5, and median 3.5, IQR 2.25–4.75, respectively, p<0.001). We observed similar trends at 24 h postoperatively, with a significantly higher difference in median LUSS in Group H (median 4, IQR 3.25–5.75) compared with Groups LR and HR (median 3, IQR 2–4 and median 3, IQR 2–3, respectively, p <0.001) (Table 3 and Figure 4).
Regarding the secondary outcome, we observed desaturation in 8 (19.5 %) patients in Group H postoperatively, compared with 3 (6.97%) patients in Group LR and one (2.38%) patient in Group HR (p<0.05). Similarly, significantly more patients in Group H (29.26%) required oxygen support postoperatively because of oxygen desaturation compared with Groups LR (9.3%) and HR (7.14%) (p<0.05) (Table 4, Figure 5). Postoperative pneumonia was observed in only one case (one patient in Group H). No cases experienced postoperative pneumonia.

Of the 132 patients that were recruited, six required postoperative ICU admission (three in Group H, one in Group LR, and two in Group HR). Because these patients were hemodynamically unstable, no intervention was performed; hence, they were excluded from the analysis. The ICU requirements did not differ significantly among the three groups.

The mean PaO$_2$/FiO$_2$ and median LUSS did not differ significantly between cases undergoing open and laparoscopic procedures administered to the individual groups. The distribution of cases did not differ significantly according to the surgical position among the three groups.

**DISCUSSION**

Our study shows that older patients undergoing major abdominal surgery benefit from RM followed by PEEP, irrespective of the FiO$_2$ used during extubation. Patients who underwent RM had less atelectasis, better oxygenation, and fewer PPCs than those who did not undergo RM.

Older patients are more prone to atelectasis due to age-related changes in respiratory mechanics, gas exchange, and immunity. In such patients, general anesthesia with neuromuscular blockade and abdominal surgeries affect respiratory functions and increase the risk of PPCs. Reducing atelectasis decreases the incidence of desaturation and reduces post-operative oxygen requirements.

We exposed Groups H and HR to a FiO$_2$ of 1 and Group LR to a FiO$_2$ of 0.4 for 10 min before extubation. RM was performed simultaneously in Groups HR and LR, while Group H did not receive
any RM. All three groups received a PEEP of 5 cm of H₂O subsequently. Atelectasis was measured in terms of LUSS and oxygenation in terms of PaO₂ and PaO₂/FiO₂.

PaO₂ and PaO₂/FiO₂ at 30 min post-extubation and 6 h post-operatively were significantly higher in Groups HR and LR compared with Group H. Although statistically significant, this difference was not clinically relevant in patients with a normal cardiopulmonary system, as the PaO₂ and PaO₂/FiO₂ values obtained in our results do not warrant the use of supplemental oxygen in Group H; however, these could have grave consequences in patients with a reduced cardiopulmonary reserve, in whom the level of decrease in PaO₂ and PaO₂/FiO₂ may be higher and could have clinical implications.

The median LUSS increased in all groups in the immediate postoperative period and 24 h postoperatively, with a statistically significant increase in Group H (p<0.001) compared to Groups HR and LR. These findings suggest that the RM may be the reason for better alveolar aeration and that the different FiO₂ values did not significantly increase atelectasis as long as the values were paired with an RM before extubation and continuous PEEP were applied. RM applied before extubation potentially reversed the atelectasis caused by abdominal surgery and general anesthesia, and this effect was maintained by sustained PEEP.

A study by Beniot et al. in patients undergoing non-abdominal surgery concluded that the use of high FiO₂ (1) at the end of surgery caused more postoperative atelectasis regardless of whether a vital capacity maneuver was performed at the end of surgery, and a low FiO₂ (0.4) completely prevented postoperative atelectasis formation. That study included two groups that were exposed to high FiO₂ (1) for a long duration before extubation, as the patients were extubated in the anesthesia room rather than the operating room. In contrast, we extubated all patients in the operating room, and they were not exposed to 100% oxygen for prolonged periods, which may explain the similar LUSS values in the HR and LR groups in our study. The previous included a small group of patients (n = 10), non-abdominal surgeries, and a single computed tomography (CT) slice to reduce radiation exposure. In another study, Ostberg et al. investigated the effect of PEEP on emergence pre-oxygenation with high FiO₂ (1) before extubation. Their results showed no significant increase in atelectasis from the baseline with the use of high FiO₂ at extubation. They included patients who underwent daycare, non-
abdominal surgeries, and single-slice CT. These results cannot be extrapolated to patients undergoing abdominal surgery who have a higher risk of pulmonary complications. Similarly, another study evaluated the effect of low FiO₂ (0.3) at extubation on postoperative atelectasis. The researchers reported no benefit regarding postoperative atelectasis in using low FiO₂ (0.3) as compared to high FiO₂ (1). They concluded that the use of intraoperative PEEP resulted in minor atelectasis at emergence and that decreased FiO₂ did not provide an added benefit. Their study included patients undergoing daycare orthopedic surgery who benefitted from the use of intraoperative PEEP without requiring RM. We suggest that RM is needed to reverse atelectasis caused by open abdominal and laparoscopic surgeries.

Our secondary outcome was measured in terms of PPCs, which included desaturation, post-operative oxygen requirement, ICU requirement, and pneumonia. The incidence of desaturation and oxygen requirements was higher in Group H than in Groups HR and LR. PPCs, in terms of ICU requirements and pneumonia, were comparable among all three groups, with only one patient from Group H being diagnosed with pneumonia. We excluded patients requiring postoperative mechanical ventilation or ICU admission from the analysis. A meta-analysis by Pei et al. suggested that RM is beneficial for decreasing the incidence of PPCs and improving post-operative oxygenation and lung mechanics. Our results were consistent with their findings.

Our study included both open and laparoscopic abdominal surgeries in both elective and emergency settings and compared the advantages of different extubation strategies in an older patient population that might benefit most from these various strategies. Subgroup analysis between open and laparoscopic surgeries did not reveal any statistically significant differences in terms of PaO₂, PaO₂/FiO₂, and LUSS. This can be explained by the fact that recruitment was performed after desufflation, 10 min before extubation. Through this study, we emphasize the importance of preventing atelectasis in older patients using RM followed by PEEP, irrespective of FiO₂. This ultimately improves respiratory function and aids in early recovery.

Limitations-
This single-center study included 132 patients. We used the LUS to calculate atelectasis; however, because ultrasound findings are subjective, errors in LUSS interpretation were possible. Although the LUS was performed by experienced anesthesiologists, it is not the gold standard. Additionally, we did not include patients with preexisting pulmonary conditions; hence, the results cannot be extrapolated to that subgroup. Finally, PEEP was not titrated post-RM, and we applied a universal minimal PEEP of 5 cm of H₂O to all patients.

CONCLUSION

The results of this study which included only older adult patients undergoing major abdominal surgeries, suggested that the use of the RM before extubation with an FiO₂ of 1 or 0.4 compared to an FiO₂ of 1 without RM resulted in improved postoperative oxygenation, reduced atelectasis as assessed by LUSS, and reduced post-operative pulmonary complications.

In conclusion, the RM before extubation was more beneficial in reducing atelectasis and postoperative pulmonary complications, irrespective of the FiO₂ concentration.