AGMR
Annals of Geriatric Medicine and Research

Original Article
pISSN 2508-4798 eISSN 2508-4909
Ann Geriatr Med Res 2024;28(2):201-208
https://doi.org/10.4235/agmr.23.0180

Effects of Different Extubation Strategies on Atelectasis in Older Adults after Major Abdominal Surgery: A Prospective Randomized Controlled Trial

Rahul Madhukar Kashyap, Pradeep Bhatia, Tanvi M. Meshram, Swati Chhabra, Rakesh Kumar

Department of Anesthesiology and Critical Care, All India Institute of Medical Sciences, Jodhpur, India

Corresponding Author:
Tanvi M. Meshram, MD
Department of Anesthesiology and Critical Care, All India Institute of Medical Sciences, AIIMS Road, Basni, Jodhpur 342005, India
E-mail: anvimeshram162@gmail.com
ORCID:
https://orcid.org/0000-0002-4625-6357

Received: October 20, 2023
Revised: January 9, 2024
Accepted: March 15, 2024

Background: 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 (FiO_2) with the recruitment maneuver (RM) during extubation on lung atelectasis postoperatively in older patients undergoing major abdominal surgery. **Methods:** We randomized a total of 126 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 FiO_2 (1), Group HR received high FiO_2 (1) with RM followed by a positive end-expiratory pressure of 5 cm H_2O, and Group LR received low FiO_2 (0.4) with RM followed by a positive end-expiratory pressure of 5 cm H_2O 10 minutes before extubation. Oxygenation and atelectasis were measured using the arterial partial pressure of oxygen (PaO_2)/FiO_2 ratios and lung ultrasound score. Postoperative pulmonary complications were recorded up to 24 hours postoperatively. **Results:** The mean PaO_2/FiO_2 at 30 minutes 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±31.70; 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 FiO_2 concentration used in older adults undergoing major abdominal surgeries. (Trail registration number: Reference No. CTRI/2022/04/042115; date of CTRI registration 25/02/2022; and date of enrolment of the first research participant 05/05/2022)

Key Words: Atelectasis, Airway extubation, Elderly, Frail older adults, Surgery

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 second, 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.[7)] reported that RM is safe in older patients and significantly improves oxygenation after major surgeries. Several studies have compared the effects of high and low fractions of inspired oxygen (FiO_2) in different age groups and non-abdominal surgeries; however, few studies have compared high and low FiO_2 with RM followed by the application of positive end-expiratory pressure (PEEP) in older patients undergoing abdominal surgery.[8-10)]

In this study, we hypothesized that a low FiO_2 (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 FiO_2 (1) with or without RM.

MATERIALS AND METHODS

After obtaining institutional ethics committee approval (No. AIIMS/IEC/2021/3738) on August 31, 2021, and registering the trial in the Clinical Trials Registry-India (CTRI; Reference 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, adhering to the applicable Consolidated Standards of Reporting Trials (CONSORT) guidelines. This study complied the ethical guidelines for authorship and publishing in the *Annals of Geriatric Medicine and Research*.[11)]

This study included patients aged ≥60 years who underwent elective and emergency major abdominal surgery. Major abdominal surgery included procedures lasting over 2 hours or with anticipated blood loss exceeding 500 mL. We excluded patients with body mass index >30 kg/m^2, severe cardiopulmonary disease, hemodynamic instability, and cerebrovascular disease.

We randomly allocated the patients at a ratio of 1:1:1 into three treatment groups—H: high FiO_2 (1) alone; HR: high FiO_2, RM, and PEEP; and LR: low FiO_2 (0.4), RM, and PEEP—based on computer-generated 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, non-invasive blood pressure measurement, and pulse oximetry. Electrodes for Bispectral Index and a train-of-four 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 minutes of pre-oxygenation 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, a respiratory rate of 12–14 breaths/min, and a PEEP of 5 cm H_2O. 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, CO_2 was insufflated into the peritoneal cavity until the intra-abdominal pressure reached 12 mmHg. During surgery, all patients received 5–8 mL/kg/hr Ringer's lactate. An epidural catheter was inserted before induction in all patients, and 0.2% ropivacaine with fentanyl (2 μg/mL) was administered at a rate of 5 mL/hr 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 <4.

Ten minutes before extubation, FiO_2 in Group H was increased to 1 (control group). Group LR patients received RM with 40 cm H_2O for 40 seconds, followed by PEEP (5 cm H_2O) and low FiO_2 (0.4). Group HR patients received RM with 40 cm H_2O for 40 seconds, followed by PEEP (5 cm H_2O) and high FiO_2 (1) (Fig. 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 minutes

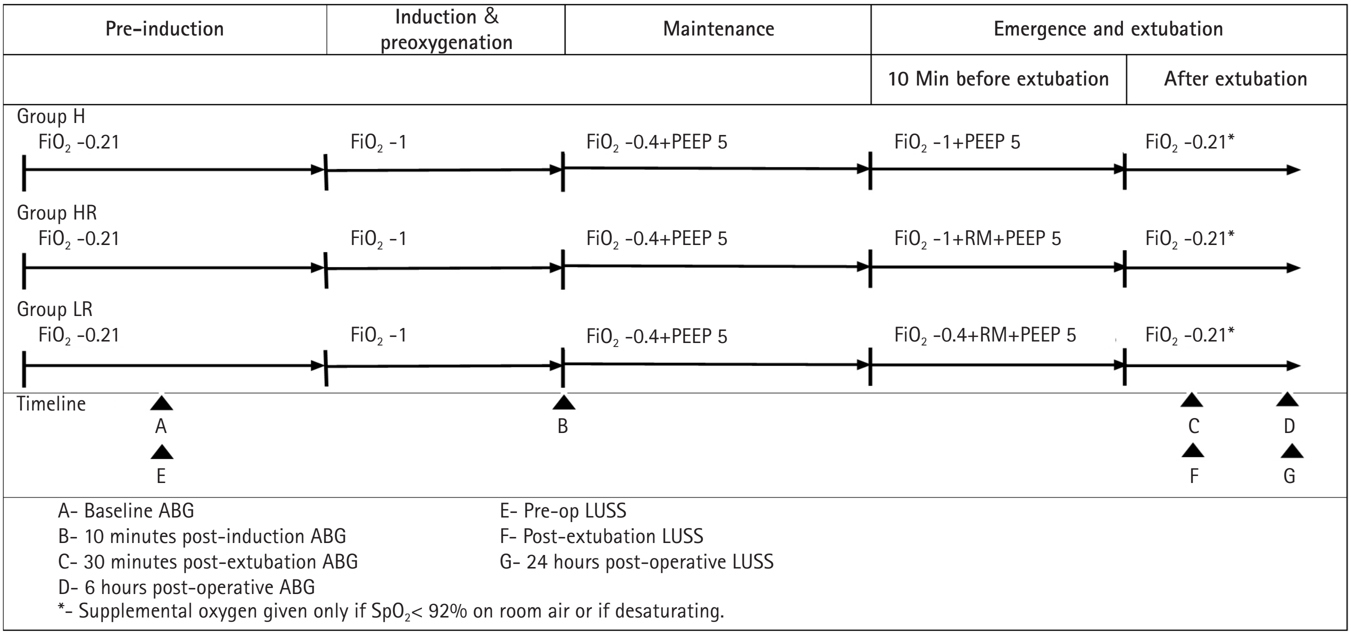

Fig. 1. Methodology. Group H, high FiO_2 (1) alone; Group HR, high FiO_2, recruitment maneuver (RM), and positive end-expiratory pressure (PEEP); and Group LR, low FiO_2 (0.4), RM, and PEEP; ABG, arterial blood gas; LUSS, lung ultrasound score.

after anesthesia induction (T2), 30 minutes after extubation (T3), and 6 hours postoperatively (T4). Lung ultrasonography (USG) was performed preoperatively, 30 minutes after extubation, and 24 hours 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 (M-Turbo; SonoSite, 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.[12] 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, PaO_2, PaO_2/FiO_2, PCO_2, HCO_3-, 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 intensive care unit (ICU) admission during the hospital stay.

Statistical Analysis

As reported by Kim et al.[13] the LUSS in the high FiO_2 group was 12.5 ± 1.73. To estimate a 10% decrease in the low FiO_2 group, we calculated a sample size of 44 per group at a 95% confidence interval, 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 (IBM, Armonk, NY, USA). 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 (Fig. 2). The baseline characteristics are summarized in Table 1. The baseline patient characteristics were comparable across the three groups.

Regarding the primary outcome, the PaO_2/FiO_2 decreased in all groups from baseline until 6 hours postoperatively. The PaO_2/FiO_2 differed significantly between Group H and Groups LR and HR 30 minutes after extubation and 6 hours after the procedure, with higher ratios in Groups LR and HR (Table 2, Fig. 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 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 hours 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,

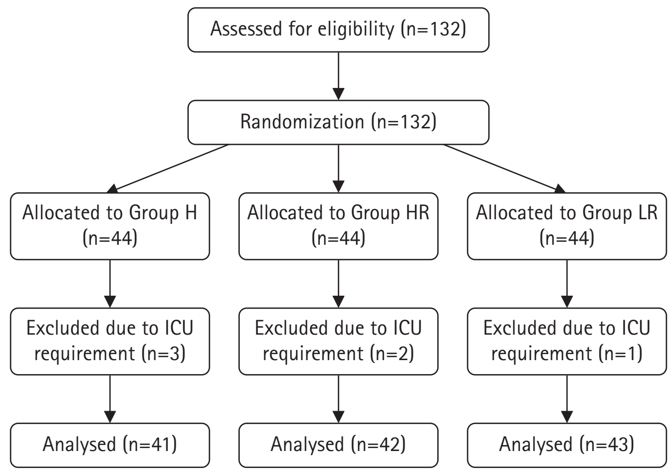

Fig. 2. Consort diagram. Group H, high FiO_2 (1) alone; Group HR, high FiO_2, recruitment maneuver (RM), and positive end-expiratory pressure (PEEP); Group LR, low FiO_2 (0.4), RM, and PEEP; ICU, intensive care unit.

Table 1. Characteristics of patient and surgery (n=126)

	Group H (n = 41)	Group HR (n = 43)	Group LR (n = 42)	p-value
Age (y)	69.02 ± 7.71	69.9 ± 8.7	66.22 ± 6.03	0.061
Sex				0.969
Male	24 (58.53)	26 (60.46)	25 (59.52)	
Female	17 (41.46)	17 (39.53)	17 (40.47)	
Weight (kg)	63.4 ± 9.91	61.5 ± 10.13	61.29 ± 11.03	0.577
BMI (kg/m^2)	23.49 ± 3.02	22.82 ± 3.29	22.78 ± 3.20	0.512
Smoking	8 (19.51)	8 (18.60)	6 (14.28)	0.804
ASA				0.322
I	20 (48.78)	27 (62.79)	22 (52.38)	
II	21 (51.21)	16 (37.20)	20 (47.61)	
Comorbidities				
Diabetes mellitus	8 (19.51)	6 (13.95)	5 (11.90)	0.650
Hypertension	11 (26.82)	10 (23.25)	11 (26.19)	0.960
Hypothyroidism	4 (9.75)	0 (0)	2 (4.76)	0.123
Parkinson's	1 (2.43)	0 (0)	1 (2.38)	0.602
Epilepsy	1 (2.43)	0 (0)	0 (0)	0.365
None	20 (48.78)	30 (69.76)	25 (59.52)	0.099
Duration of surgery (min)	273.78 ± 78.49	304.28 ± 86.9	297.79 ± 88.14	0.229
Type of surgery administered				0.214
Open	21 (51.2)	29 (69.04)	28 (65.1)	
Laparoscopic	20 (48.7)	13 (30.9)	15 (34.8)	

Values are presented as mean ± standard deviation or number (%).
Group H, high FiO_2 (1) alone; Group HR, high FiO_2, recruitment maneuver (RM), and positive end-expiratory pressure (PEEP); Group LR, low FiO_2 (0.4), RM, and PEEP; BMI, body mass index; ASA, American Society of Anesthesiologists physical status classification.

Table 2. Comparison of PaO_2/FiO_2 between the three groups (n=126)

Parameter	Group	Baseline	10 minutes after induction	30 minutes after extubation	6 hours postoperative
PaO_2/FiO_2	Group H	400.27 ± 23.16	383.03 ± 50.45	355.37 ± 31.7	359.06 ± 29.97
	Group LR	409.86 ± 28.35	403.79 ± 41.75	381.97 ± 24.97	382.93 ± 24.56
	Group HR	410.53 ± 21.16	406.12 ± 48.85	390.71 ± 29.55	387.41 ± 34.84
	p-value (inter)	0.106	0.053	< 0.001*	< 0.001*
Post-hoc (p-value)	H vs. LR	0.175	0.112	< 0.001*	0.001*
	H vs. HR	0.140	0.070	< 0.001*	< 0.001*
	LR vs. HR	0.991	0.972	0.346	0.774

Values are presented as mean±standard deviation.
Group H, high FiO_2 (1) alone; Group HR, high FiO_2, recruitment maneuver (RM), and positive end-expiratory pressure (PEEP); Group LR, low FiO_2 (0.4), RM, and PEEP.
*p<0.05.

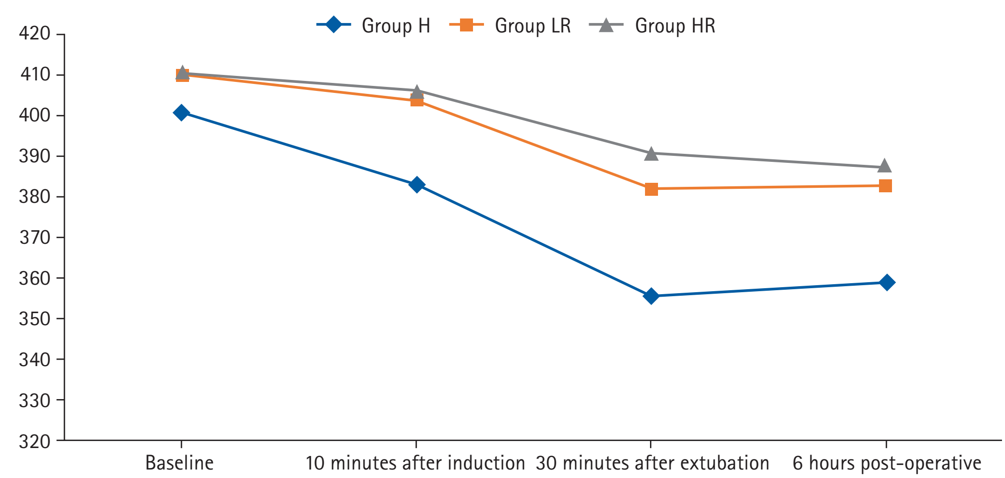

Fig. 3. Comparison of PaO_2/FiO_2 between the three groups. Group H, high FiO_2 (1) alone; Group HR, high FiO_2, recruitment maneuver (RM), and positive end-expiratory pressure (PEEP); and Group LR, low FiO_2 (0.4), RM, and PEEP.

respectively; $p < 0.001$) (Table 3, Fig. 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 1 (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, Fig. 5). Postoperative pneumonia was observed in only one patient (from Group H).

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). These patients were hemodynamically unstable and, therefore, 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, regardless of the FiO_2 used during extubation. Patients who underwent RM experienced 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 affects respiratory functions and increases the risk of PPCs.[1,2] Reducing atelectasis decreases the incidence of desaturation and reduces postoperative 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 minutes before extubation. RM was performed

Table 3. Comparison of median LUSS between the three groups (n=126)

	Group H	Group LR	Group HR	p-value
Preoperative				
Anterior region	0 (0–0)	0 (0–0)	0 (0–0)	0.167
Lateral region	1 (1–0)	0 (1–0)	1 (1–0)	0.357
Posterior region	1.5 (2–1)	1 (2–0.25)	1 (2–0)	0.305
Total	2 (2–3)	2 (1–3)	2 (1–3)	0.177
30 minutes postoperative				
Anterior region	0 (1–0)	0 (0–0)	0 (0–0)	0.019*
Lateral region	2 (3–2)	1.5 (2–1)	1 (2–0.5)	<0.001*
Posterior region	3 (4–2.5)	2 (4–2)	2 (3–2)	<0.001*
Total	6 (5–7)	3 (3–5)	3.5 (2.25–4.75)	<0.001*
24 hours postoperative				
Anterior region	0 (0–0)	0 (0–0)	0 (0–0)	0.560
Lateral region	1 (2–1)	1 (1–0)	0 (1–0)	<0.001*
Posterior region	2 (3–2)	2 (2–1)	2 (2–1)	<0.001*
Total	4 (3.25–5.75)	3 (2–4)	3 (2–3)	<0.001*

Values are presented as median (interquartile range).
Group H, high FiO_2 (1) alone; Group HR, high FiO_2, recruitment maneuver (RM), and positive end-expiratory pressure (PEEP); Group LR, low FiO_2 (0.4), RM, and PEEP; LUSS, lung ultrasound score.
*p<0.05.

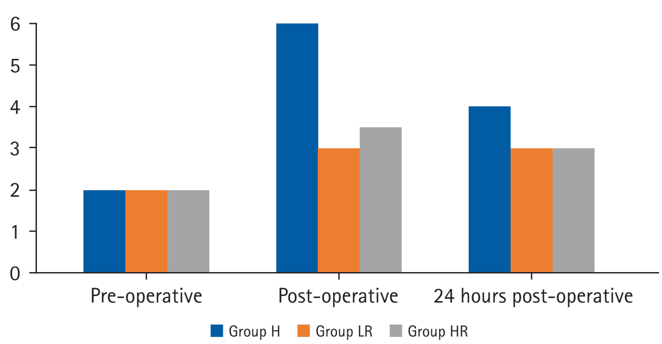

Fig. 4. Comparison of median LUSS between the three groups. Group H, high FiO_2 (1) alone; Group HR, high FiO_2, recruitment maneuver (RM), and positive end-expiratory pressure (PEEP); and Group LR, low FiO_2 (0.4), RM, and PEEP; LUSS, lung ultrasound score.

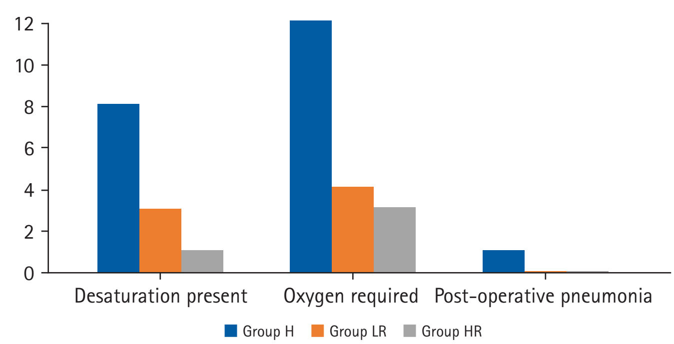

Fig. 5. Distribution of cases according to complications experienced in the three groups. Group H, high FiO_2 (1) alone; Group HR, high FiO_2, recruitment maneuver (RM), and positive end-expiratory pressure (PEEP); and Group LR, low FiO_2 (0.4), RM, and PEEP.

Table 4. Comparison of PPCs between the three groups (n=126)

PPCs	Group H (n=41)	Group LR (n=43)	Group HR (n=42)	p-value
Desaturation	8 (19.51)	3 (6.97)	1 (2.38)	0.023*
Oxygen requirement	12 (29.26)	4 (9.30)	3 (7.14)	0.008*
Postoperative pneumonia	1 (2.43)	0 (0)	0 (0)	0.352

Values are presented as number (%).
Group H, high FiO_2 (1) alone; Group HR, high FiO_2, recruitment maneuver (RM), and positive end-expiratory pressure (PEEP); Group LR, low FiO_2 (0.4), RM, and PEEP; PPC, postoperative pulmonary complication.
*p<0.05.

simultaneously in Groups HR and LR, while Group H did not receive any RM. All three groups received a PEEP of 5 cm H_2O subsequently. Atelectasis was measured in terms of LUSS and oxygenation in terms of PaO_2 and PaO_2/FiO_2.

PaO_2 and PaO_2/FiO_2 at 30 minutes post-extubation and 6 hours postoperatively were significantly higher in Groups HR and LR compared to Group H. Although statistically significant, this difference was not clinically relevant in patients with a normal cardiopulmonary system, as the PaO_2 and PaO_2/FiO_2 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 PaO_2 and PaO_2/FiO_2 may be higher and could have clinical implications.

The median LUSS increased in all groups in the immediate postoperative period and 24 hours 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 FiO_2 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.[10] in patients undergoing non-abdominal surgery concluded that the use of high FiO_2 (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 FiO_2 (0.4) completely prevented postoperative atelectasis formation. That study included two groups that were exposed to high FiO_2 (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 study included a small group of patients ($n = 10$), non-abdominal surgeries, and a single computed tomography (CT) slice to reduce radiation exposure.[10] In another study, Ostberg et al.[14] investigated the effect of PEEP on emergence pre-oxygenation with high FiO_2 (1) before extubation. Their results showed no significant increase in atelectasis from the baseline with the use of high FiO_2 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 FiO_2 (0.3) at extubation on postoperative atelectasis. The researchers reported no benefit regarding postoperative atelectasis in using low FiO_2 (0.3) as compared to high FiO_2 (1). They concluded that the use of intraoperative PEEP resulted in minor atelectasis at emergence and that decreased FiO_2 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.[15] 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, postoperative 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.[5] suggested that RM is beneficial for decreasing the incidence of PPCs and improving postoperative 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 PaO_2, PaO_2/FiO_2, or LUSS. This can be explained by the fact that recruitment was performed after desufflation, 10 minutes before extubation. Through this study, we emphasize the importance of preventing atelectasis in older patients using RM followed by PEEP, irrespective of FiO_2. 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 H_2O 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 FiO_2 of 1 or 0.4 compared to an FiO_2 of 1 without RM resulted in improved postoperative oxygenation, reduced atelectasis as assessed by LUSS, and reduced postoperative pulmonary complications.

In conclusion, RM before extubation was more beneficial in reducing atelectasis and postoperative pulmonary complications, regardless of the FiO_2 concentration.

ACKNOWLEDGMENTS

CONFLICT OF INTEREST

The researchers claim no conflicts of interest.

FUNDING

None.

AUTHOR CONTRIBUTIONS

Conceptualization, PB, TMM; Data curation, RMK; Investigation, RMK, TNM; Supervision, PB; Writing–original draft, RMK; Writing–review & editing, SC, RK.

REFERENCES

1. Alvis BD, Hughes CG. Physiology considerations in geriatric patients. Anesthesiol Clin 2015;33:447-56.
2. Staheli B, Rondeau B. Anesthetic considerations in the geriatric population. Treasure Island (FL): StatPearls; 2023.
3. Entriken C, Pritts TA. Perioperative pulmonary support of the elderly. Curr Geriatr Rep 2021;10:167-74.
4. Cho SA, Kim JH, Cho CK, Sung TY. The effect of neuromuscular blockade reversal agents on postoperative pulmonary complications in patients undergoing femur fracture repair surgery: a retrospective observational study. Ann Geriatr Med Res 2023;27:212-9.
5. Hedenstierna G, Edmark L. Mechanisms of atelectasis in the perioperative period. Best Pract Res Clin Anaesthesiol 2010;24:157-69.
6. Pei S, Wei W, Yang K, Yang Y, Pan Y, Wei J, et al. Recruitment maneuver to reduce postoperative pulmonary complications after laparoscopic abdominal surgery: a systematic review and meta-analysis. J Clin Med 2022;11:5841.
7. Ning B, Li YS, Ma YJ, Ma JZ, Liu T. [Effects of recruitment maneuver on elderly patients after major operations]. Zhongguo Wei Zhong Bing Ji Jiu Yi Xue 2008;20:618-20.
8. Tusman G, Bohm SH, Tempra A, Melkun F, Garcia E, Turchetto E, et al. Effects of recruitment maneuver on atelectasis in anesthetized children. Anesthesiology 2003;98:14-22.
9. Eskandr AM, Atallah HA, Sadik SA, Mohamemd MS. The effect of inspired oxygen concentration on postoperative pulmonary atelectasis in obese patients undergoing laparoscopic cholecystectomy: a randomized-controlled double-blind study. Res Opin Anesth Intensive Care 2019;6:287-93.
10. Benoit Z, Wicky S, Fischer JF, Frascarolo P, Chapuis C, Spahn DR, et al. The effect of increased FIO(2) before tracheal extubation on postoperative atelectasis. Anesth Analg 2002;95:1777-81.
11. Noh JH, Jung HW, Ga H, Lim JY. Ethical guidelines for publishing in the Annals of Geriatric Medicine and Research. Ann Geriatr Med Res 2022;26:1-3.
12. Monastesse A, Girard F, Massicotte N, Chartrand-Lefebvre C, Girard M. Lung ultrasonography for the assessment of perioperative atelectasis: a pilot feasibility study. Anesth Analg 2017;124:494-504.
13. Kim BR, Lee S, Bae H, Lee M, Bahk JH, Yoon S. Lung ultrasound score to determine the effect of fraction inspired oxygen during alveolar recruitment on absorption atelectasis in laparoscopic surgery: a randomized controlled trial. BMC Anesthesiol 2020;20:173.
14. Ostberg E, Thorisson A, Enlund M, Zetterstrom H, Hedenstierna G, Edmark L. Positive end-expiratory pressure and postoperative atelectasis: a randomized controlled trial. Anesthesiology 2019;131:809-17.
15. Edmark L, Auner U, Lindback J, Enlund M, Hedenstierna G. Post-operative atelectasis: a randomised trial investigating a ventilatory strategy and low oxygen fraction during recovery. Acta Anaesthesiol Scand 2014;58:681-8.