Impact of positive end-expiratory pressure with alveolar recruitment maneuver on respiratory and oxygenation parameters of patients during laparoscopic bariatric surgery

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Abstract. – OBJECTIVE: Laparoscopic bariatric surgery is frequently associated with disturbances in respiratory mechanics. An alveolar recruitment maneuver (ARM) with positive end-expiratory pressure (PEEP) is a strategy to overcome such respiratory conditions. This study aimed to evaluate the effect of ARM+PEEP on intraoperative and postoperative respiratory and hemodynamic parameters of patients with laparoscopic bariatric surgery.

PATIENTS AND METHODS: Patients who underwent laparoscopic bariatric surgery between 2009 and 2016 were retrospectively evaluated. The study sample was divided into four groups based on PEEP values and the presence of ARM: Group PEEP 5 (5 cm H₂O PEEP only), Group PEEP 5/RM (5 cm H₂O PEEP plus ARM), Group PEEP 10 (10 cm H₂O PEEP only), Group PEEP 10/RM (10 cm H₂O PEEP plus ARM). Patients’ demographic characteristics, ventilatory, respiratory, and oxygenation parameters were recorded. Oxygenation index (PaO₂/FiO₂) was the study’s primary outcome.

RESULTS: There were 156, 158, 299, and 210 patients in Groups PEEP 5, PEEP 5/RM, PEEP 10, and PEEP 10/RM, respectively. Tidal volume, driving tidal volume/compliance, PaO₂, PaO₂/FiO₂, and PaCO₂ were significantly lower in Groups PEEP 5 and PEEP 5/RM, whereas SpO₂ and FiO₂ were significantly higher in Groups PEEP 5 and PEEP 5/RM (p<0.05). Patients in Group PEEP 5 had significantly higher end-tidal carbon dioxide (EtCO₂) values than those of other groups (p<0.001). Patients in Group PEEP 5/RM had significantly higher SpO₂ values than those in Group PEEP 5 (p<0.001). Rate of postoperative atelectasis was significantly higher in Group PEEP 5/RM compared to the other groups (p=0.011).

CONCLUSIONS: A PEEP level of at least 10 cm H₂O with ARM improved intraoperative respiratory parameters and caused a significant reduction in postoperative atelectasis.

Key Words: Obesity, Bariatric surgery, Laparoscopy, Positive end-expiratory pressure, Alveolar recruitment, Atelectasis.

Introduction

Laparoscopic bariatric surgery leads to challenging respiratory conditions due to the reduced end-expiratory lung volume, functional residual capacity, and lung compliance in obese patients. A commonly encountered problem following bariatric surgery is the increased incidence of atelectasis or alveolar hypoventilation with disturbances in the ventilation and perfusion mechanics. In obese patients who had laparoscopic bariatric surgery, overinflation of the non-atelectatic areas and cyclic tidal recruitment and de-recruitment, all contribute to the development of ventilation-induced lung injury and postoperative pulmonary complications. In this context, several ventilatory strategies or maneuvers have been proposed to improve gas exchange for anesthetic management of these patients. One of these maneuvers is the alveolar recruitment maneuver (ARM) with positive end-expiratory pressure (PEEP), which has been investigated in obese patients in the context of different surgical operations. Theoretically, the ARM with high PEEP is expected to prevent and reverse alveolar collapse and improve end-expiratory lung volume.

The relationship between such protective intraoperative mechanical ventilation techniques and postoperative pulmonary complications has been addressed in the literature. Accordingly, the ventilation strategy that utilized low tidal volumes with
Positive end-expiratory pressure and alveolar recruitment

PEEP was superior to high tidal volumes with no PEEP, given the pulmonary and extrapulmonary complications. The ARM approach with high PEEP has been suggested as the preferred intraoperative mechanical ventilation for obese patients undergoing laparoscopic bariatric surgery. The open-lung PEEP, which utilizes the ARM and an individualized PEEP value to prevent the closure of the lungs, is another approach.

Despite the expected physiological benefits of the lung-protective strategies, several researchers failed to show any reduction in the postoperative pulmonary complications via low tidal volumes with higher PEEP with alveolar recruitment maneuvers. To give an example, in the Protective Intraoperative Ventilation with Higher Versus Lower Levels of Positive End-Expiratory Pressure in Obese Patients (PROBESE) trial, no significant reduction was achieved in the rate of postoperative pulmonary complications via low tidal volumes with higher PEEP (12 cm H2O) compared to the use of ARM with low PEEP (4 cm H2O) in obese patients undergoing laparoscopic bariatric surgery. Nevertheless, high PEEP reportedly resulted in better intraoperative lung function parameters. Additionally, it was stated that higher PEEP administration might be a factor for barotrauma due to the increased airway pressure.

There is another controversy on whether ARM and PEEP separately affect respiratory mechanics. Due to the technical difficulties leading to the potential limitations of the applications and measurements of the ARM or PEEP, the factors pertaining to the protective mechanical ventilation techniques that play a more critical role in obtaining the beneficial effects are unclear.

In the light of the foregoing, it is hypothesized in this study that higher PEEP applications with the ARM might be more beneficial in improving the respiratory mechanics in obese patients undergoing laparoscopic bariatric surgery. In this context, this study was carried out to evaluate the effect of different PEEP applications with and without the ARM on the intraoperative and early postoperative respiratory and hemodynamic parameters of patients undergoing laparoscopic bariatric surgery.

Patients and Methods

Study Design

The population of this retrospective study consisted of consecutive patients who underwent laparoscopic bariatric surgery in two health centers between 2009 and 2016. The study protocol was approved by the Pamukkale University Local Ethic Committee (Decision number 60116787-020/56142 and date 20.08.2019). The study was carried out in accordance with the principles set forth in the Declaration of Helsinki. Written informed consent could not be obtained from the patients due to the study’s retrospective design and the data’s unanimity.

Study Groups

Before the bariatric surgery, all patients underwent a multidisciplinary evaluation featuring cardiology, chest diseases, and endocrine consultations. Surgeries were performed by two different surgical teams with similar experience in laparoscopic bariatric operations.

As per the relevant guidelines, patients with body mass index (BMI) values higher than 40 kg/m2 or 35-40 kg/m2 with at least one comorbidity were included in the study, whereas the patients with an American Society of Anesthesiologists (ASA) grade >3, previous obesity surgery, abnormal pulmonary function test results (less than 70% of expected values of respiratory function tests), chronic severe cardiac and respiratory diseases, and incomplete baseline or clinical data were excluded from the study.

Interventions

A standardized anesthetic and surgical approach were applied in the two health centers where this study was conducted. The vital signs monitored throughout the operation included heart rate and mean blood pressure (MBP), static respiratory system compliance, end-tidal carbon dioxide (EtCO2), and SpO2 values.

As a general policy, two PEEP values (5 and 10 cm H2O) were applied in each health center. Depending on the discretion of the attending anesthesiologist, the ARM systems with a peak inspiratory pressure of 40 cm H2O (two sustained inflations for 10 seconds) were performed selectively. The clinical data regarding the anesthetic management of the patients were retrospectively evaluated based on the PEEP values and the ARM features obtained from the patients’ medical records.

The patients included in the study were divided into four groups:

1. Group PEEP 5: Patients with intraoperative PEEP application (5 cm H2O).
2. Group PEEP 5/RM: Patients with intraopera-
tive PEEP application (5 cm H₂O) plus ARM.
3. Group PEEP 10: Patients with intraoperative PEEP application (10 cm H₂O).
4. Group PEEP 10/RM Patients with intraoperative PEEP application (10 cm H₂O) plus ARM.

Variables

The demographic and clinical data of the patients, including age, gender, and BMI data, were obtained retrospectively from the databases of the respective health centers. Patients’ comorbidities and ASA grades were analyzed. Additionally, intraoperative data about the duration of anesthesia and surgery and postoperative follow-up data (length of stay and intra- and postoperative complications) were recorded. As for the intraoperative ventilatory, respiratory, and oxygenation variables, tidal volume, FiO₂, compliance, driving pressure (cm H₂O), FiO₂/PaO₂ (Horowitz ratio), PaCO₂, EtCO₂, SpO₂, pH, and HCO₃ were measured.

Statistical Analysis

The study’s primary outcome was oxygenation index (PaO₂/FiO₂), and the secondary outcomes were postoperative and intraoperative respiratory complications, including atelectasis, bronchospasm, tachycardia, and hypotensive attacks. Descriptive statistics were expressed as mean ± standard deviation values in the case of continuous variables determined to conform to the normal distribution, as median with minimum-maximum values in the case of continuous variables determined not to conform to the normal distribution, and as numbers and percentages in the case of categorical variables. The Shapiro-Wilk, Kolmogorov-Smirnov, and Anderson-Darling tests were used to analyze the normal distribution characteristics of the numerical variables.

In order to compare the differences between categorical variables, the Pearson’s chi-squared test was used in 2x2 tables, and the Fisher-Freeman-Halton test was used in RxC tables. The Kruskal-Wallis’ test was used to compare more than two independent groups with variables determined not to conform to the normal distribution. In the event of non-parametric tests, the differences between the groups were evaluated with the Dwass-Steel-Critchlow-Fligner test.

Jamovi project (Jamovi, version 2.2.5.0, 2022, retrieved from https://www.jamovi.org) and JASP (Jeffreys’ Amazing Statistics Program, version 0.16, 2022, retrieved from https://jasp-stats.org) software packages were used in the statistical analyses. Probability (p) values ≤0.5 were deemed to indicate statistical significance.

Results

There were 156, 158, 299, and 210 patients in Groups PEEP 5, PEEP 5/RM, PEEP 10, and PEEP 10/RM, respectively (Table I). Significant differences were found between the groups in terms of demographic and clinical characteristics. Accordingly, the patients in Groups PEEP 5 were significantly younger than those in Group PEEP 10 (p=0.017). The groups have not differed significantly in terms of gender (p=0.841). On the other hand, the patients in Groups PEEP 10 and PEEP 10/RM were significantly more obese than those in the groups PEEP 5 and PEEP 5/RM (p<0.001). Furthermore, the frequencies of comorbidities were significantly different between the groups. Accordingly, the rates of patients with diabetes mellitus and hypertension were significantly higher in Groups PEEP 10 and PEEP 10/RM than in other groups (p<0.001 and p=0.002, respectively). Additionally, there were significant differences between the groups in the incidence of obstructive sleep apnea syndrome (OSAS) and Mallampati scores (p<0.001 and p=0.009, respectively). There was no significant difference between the groups in other clinical characteristics (p>0.05) (Table I).

The distribution of the intraoperative findings by the study groups is shown in Table II. Accordingly, the anesthesia time was similar between the groups (p=0.553), whereas the duration of surgery was significantly higher in Group PEEP 10/RM than in Group PEEP 5/RM (p=0.022).

Significant differences were observed between the groups in terms of intraoperative respiratory and oxygenation parameters (Table II). Accordingly, the tidal volume, driving tidal volume/compliance, PaO₂, PaO₂/FiO₂ (Horowitz ratio), and PaCO₂ values were significantly lower in Groups PEEP 5 and PEEP 5/RM than those in Groups PEEP 10 and PEEP 10/RM (p<0.05 for all cases). Additionally, the SpO₂ and FiO₂ values were significantly higher in the Groups PEEP 5 and PEEP 5/RM than in other groups (p<0.05). The patients in Group PEEP 5 had significantly higher EtCO₂ values than those in the other three
Positive end-expiratory pressure and alveolar recruitment

There were significant differences in SpO₂ measurements between Group PEEP 5 and Group PEEP 5/RM (p<0.001). The patients in Group PEEP 5/RM had higher SpO₂ values than those in Group PEEP 5. The PCO₂ values in PEEP 5 and PEEP 10/RM groups were similar (p=0.677) (Figure 1, Figure 2).

The heart rate in Group PEEP 10 was significantly higher than in Groups PEEP 5 and PEEP 5/RM (p=0.019). The mean arterial blood pressure values differed significantly in paired group comparisons (p<0.001 for all cases). Accordingly, the highest and lowest arterial blood pressure values were determined in Groups PEEP 5 and PEEP 10/RM, respectively.

Furthermore, significant differences were detected between Groups PEEP 5 and PEEP 10 in arterial blood gas measurements (pH and HCO₃⁻) (p<0.001 for both cases).

The rate of postoperative atelectasis was significantly higher in Group PEEP 5/RM than in the other three groups (p=0.011). There was no significant difference between the groups in other intraoperative and postoperative parameters (Table III). The median length of stay (LoS) was four days in all groups. Nevertheless, LoS was significantly longer in groups PEEP 5 and PEEP 5/RM than in other groups (p=0.011).

Discussion

The study findings revealed that ARM with a PEEP of 10 cm H₂O is a practical approach to improve intraoperative respiratory and oxygenation parameters and prevent postoperative atelectasis in patients who underwent bariatric surgery. Patients with a PEEP of 5 cm H₂O with ARM had significantly higher rates of postoperative atelectasis than the other three groups.

The ARM is used to obtain a sustained increase in airway pressure during anesthesia and surgical procedures. These maneuvers are frequently helpful in applying high pressures to the respiratory system. Nevertheless, ventilator-associated lung injury might be the endpoint. The benefit of PEEP in preventing the development of atelectasis in obese patients has been addressed in the literature. In this context, it was reported that the application of PEEP at the induction of anesthesia, either stand-alone or in combination with other techniques, prevent-
Table II. Comparison of the intraoperative findings between the groups.

<table>
<thead>
<tr>
<th>Intraoperative measurements</th>
<th>Group PEEP 5 (n = 156)</th>
<th>Group PEEP 5/RM (n = 158)</th>
<th>Group PEEP 10 (n = 299)</th>
<th>Group PEEP 10/RM (n = 210)</th>
<th>(p^*)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anesthesia time (min)</strong></td>
<td>11.0 [7.0-13.0]</td>
<td>11.0 [7.0-13.0]</td>
<td>11.0 [7.0-13.0]</td>
<td>11.0 [7.0-13.0]</td>
<td>0.553</td>
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<tr>
<td><strong>Operation time (min)</strong></td>
<td>120.0 [110.0-160.0]</td>
<td>120.0 [90.0-160.0]</td>
<td>120.0 [90.0-160.0]</td>
<td>130.0 [90.0-160.0]</td>
<td><strong>0.027</strong></td>
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<tr>
<td><strong>Ventilatory parameters</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>FiO(_2) (%)</strong></td>
<td>40.0 [40.0-60.0]</td>
<td>40.0 [40.0-60.0]</td>
<td>40.0 [40.0-50.0]</td>
<td>40.0 [40.0-60.0]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
<tr>
<td><strong>Tidal volume (mL)</strong></td>
<td>490.0 [344.0-545.0]</td>
<td>490.0 [365.0-550.0]</td>
<td>510.0 [425.0-545.0]</td>
<td>510.0 [425.0-545.0]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
<tr>
<td><strong>Compliance (ml/cm H(_2)O)</strong></td>
<td>35.0 [29.0-39.0]</td>
<td>35.0 [30.0-40.0]</td>
<td>35.0 [29.0-39.0]</td>
<td>35.0 [30.0-39.0]</td>
<td>0.576</td>
</tr>
<tr>
<td><strong>Driving tidal volume/compliance</strong></td>
<td>13.8 [9.8-17.5]</td>
<td>13.8 [9.9-17.7]</td>
<td>14.3 [12.3-17.8]</td>
<td>14.3 [12.3-17.7]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
<tr>
<td><strong>Respiratory and oxygenation parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>PaO(_2) (mm H(_g))</strong></td>
<td>97.0 [67.0-99.0]</td>
<td>97.0 [78.0-99.0]</td>
<td>98.0 [78.0-99.0]</td>
<td>98.0 [78.0-99.0]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
<tr>
<td><strong>PaO(_2)/FiO(_2), (Horowitz ratio)</strong></td>
<td>2.4 [1.3-2.5]</td>
<td>2.3 [1.3-2.5]</td>
<td>2.5 [1.6-2.5]</td>
<td>2.5 [1.5-2.5]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
<tr>
<td><strong>PaCO(_2) (mm H(_g))</strong></td>
<td>38.0 [30.0-45.0]</td>
<td>37.0 [30.0-44.0]</td>
<td>39.0 [24.0-45.0]</td>
<td>39.0 [34.0-45.0]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
<tr>
<td><strong>EtCO(_2) (mm H(_g))</strong></td>
<td>38.0 [32.0-44.0]</td>
<td>36.0 [32.0-45.0]</td>
<td>36.0 [33.0-42.0]</td>
<td>36.0 [33.0-42.0]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
<tr>
<td><strong>SpO(_2) (%)</strong></td>
<td>97.0 [93.0-100.0]</td>
<td>98.0 [93.0-99.0]</td>
<td>96.0 [90.0-99.0]</td>
<td>96.0 [91.0-99.0]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
<tr>
<td><strong>Hemodynamic and metabolic parameters</strong></td>
<td></td>
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<tr>
<td><strong>Heart rate (/min)</strong></td>
<td>70.0 [53.0-93.0]</td>
<td>71.0 [53.0-93.0]</td>
<td>74.0 [52.0-106.0]</td>
<td>72.5 [52.0-105.0]</td>
<td><strong>0.039</strong></td>
</tr>
<tr>
<td><strong>Mean arterial pressure (mm H(_g))</strong></td>
<td>100.0 [59.0-118.0]</td>
<td>86.0 [64.0-119.0]</td>
<td>78.0 [52.0-98.0]</td>
<td>64.0 [56.0-82.0]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>7.4 [7.3-7.5]</td>
<td>7.4 [7.3-7.7]</td>
<td>7.4 [7.3-7.5]</td>
<td>7.4 [7.3-7.5]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
<tr>
<td><strong>HCO(_3) (mEq/L)</strong></td>
<td>24.0 [22.0-26.0]</td>
<td>24.0 [22.0-26.0]</td>
<td>24.0 [22.0-26.0]</td>
<td>24.0 [22.0-26.0]</td>
<td>&lt; <strong>0.001</strong></td>
</tr>
</tbody>
</table>

\(\dagger\): n (%), \(\ddagger\): mean ± standard deviation, \(\ddagger\): median [min-max]. PEEP: positive end-expiratory pressure, RM: recruitment maneuver. \(^*\): Kruskal-Wallis H test.
Figure 1. Values of ventilatory parameters in the groups.

Figure 2. Values of respiratory and oxygenation parameters in the groups.
ed atelectasis. Higher intraoperative respiratory system compliance, better oxygenation, and ventilation distribution to the dependent lung areas were reported in patients with PEEP and ARM. However, multiple deep breaths as a type of ARM were not as effective as PEEP (10 cm H\textsubscript{2}O) or PEEP plus multiple deep breaths. In contrast, Wei et al\cite{19} found that repeated ARM with and without a PEEP of 8 cm H\textsubscript{2}O improved early postoperative oxygenation, shortened the time to extubation, and resulted in lower airway pressure and less hemodynamic impairment in patients with bariatric surgery. In sum, the duration of the improvements in the oxygenation and the use of PEEP with an optimum pressure level for each patient remain controversial\cite{5}.

Previous studies\cite{1} have revealed improvements in respiratory dynamics, including a reduction in driving pressure, but not in clinical outcomes pertaining to the improvements in the respiratory parameters. Simon et al\cite{1} found that lung recruitment with higher PEEP could not be preserved after tracheal extubation in obese patients. Hemodynamic depressive effects treated via vasoactive medications should be considered in these patients. Although high PEEP levels with ARM approaches seemed to benefit obese patients during surgical treatment modalities, the absolute benefits of these approaches over low PEEP-based strategies remain controversial\cite{1}.

Several respiratory parameters have been used to measure the efficiency of such approaches via oxygenation status\cite{25}. In this context, \text{PaO}_{2} / \text{FiO}_{2} ratio, the sum of \text{PaO}_{2} and \text{PaCO}_{2}, plateau pressure, and mean airway pressure values have been studied\cite{24}. Yet, no clinical improvements in the postoperative respiratory parameters and complications have been reported apart from statistically significant results\cite{26}. In this context, postoperative atelectasis was detected more frequently in patients with PEEP of 5 cm H\textsubscript{2}O with ARM in this study. The atelectasis rate was lower in patients with PEEP of 5 cm H\textsubscript{2}O, ARM plus PEEP of 10 cm H\textsubscript{2}O than in patients with stand-alone PEEP of 10 cm H\textsubscript{2}O. Several authors\cite{27,28,29,30} suggested that low PEEP levels were insufficient to provide enough stability to prevent lung collapse after ARM. For this reason, ARM was not used in patients with low PEEP levels (4 to 5 cm H\textsubscript{2}O) in some studies\cite{4,6}. In comparison, 4 cm H\textsubscript{2}O and 12 cm H\textsubscript{2}O PEEP values for low and high PEEP groups have been used in the PROBESE randomized clinical trial\cite{6}. Nevertheless, in the said study, no reduction was reported in postoperative pulmonary complications. Simon et al\cite{1} performed a

| Table III. Intraoperative and postoperative complications in the study groups. |
|----------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|---|
|                                  | Group PEEP 5                  | Group PEEP 5/RM               | Group PEEP 10                 | Group PEEP 10/RM               |   |
|                                  | \(n = 156\)                  | \(n = 158\)                  | \(n = 299\)                  | \(n = 210\)                  |   |
| Intraoperative complications\footnote{\textsuperscript{1}} |                                |                               |                               |                               |   |
| Allergic reaction yes            | \text{1 (0.6)} \textsuperscript{\textasteriskcentered} | \text{3 (1.9)} \textsuperscript{\textasteriskcentered} | \text{3 (1.0)} \textsuperscript{\textasteriskcentered} | \text{2 (1.0)} \textsuperscript{\textasteriskcentered} | \text{0.770*} |
| Tachycardia yes                  | \text{5 (3.2)} \textsuperscript{\textasteriskcentered} | \text{3 (1.9)} \textsuperscript{\textasteriskcentered} | \text{13 (4.3)} \textsuperscript{\textasteriskcentered} | \text{9 (4.3)} \textsuperscript{\textasteriskcentered} | \text{0.547*} |
| Hypotensive attacks yes          | \text{8 (5.1)} \textsuperscript{\textasteriskcentered} | \text{4 (2.5)} \textsuperscript{\textasteriskcentered} | \text{16 (5.4)} \textsuperscript{\textasteriskcentered} | \text{17 (8.1)} \textsuperscript{\textasteriskcentered} | \text{0.140*} |
| Bronkospazm yes                 | \text{6 (3.8)} \textsuperscript{\textasteriskcentered} | \text{8 (5.1)} \textsuperscript{\textasteriskcentered} | \text{5 (1.7)} \textsuperscript{\textasteriskcentered} | \text{6 (2.9)} \textsuperscript{\textasteriskcentered} | \text{0.201*} |
| Awakening                        | \text{1 (16.7)} \textsuperscript{\textasteriskcentered} | \text{4 (50.0)} \textsuperscript{\textasteriskcentered} | \text{1 (20.0)} \textsuperscript{\textasteriskcentered} | \text{2 (33.3)} \textsuperscript{\textasteriskcentered} | \text{0.587*} |
| Induction                        | \text{5 (83.3)} \textsuperscript{\textasteriskcentered} | \text{4 (50.0)} \textsuperscript{\textasteriskcentered} | \text{4 (80.0)} \textsuperscript{\textasteriskcentered} | \text{4 (66.7)} \textsuperscript{\textasteriskcentered} |   |
| Postoperative complications      |                                |                               |                               |                               |   |
| Fever (°C)\footnote{\textsuperscript{\textasteriskcentered}} | \text{37.0 [36.0-38.5]} \textsuperscript{\textasteriskcentered} | \text{37.0 [36.0-38.6]} \textsuperscript{\textasteriskcentered} | \text{36.9 [36.3-38.2]} \textsuperscript{\textasteriskcentered} | \text{37.0 [36.1-37.9]} \textsuperscript{\textasteriskcentered} | \text{0.270**} |
| Atelectasis yes\footnote{\textsuperscript{\textasteriskcentered}} | \text{19 (12.2)%} \textsuperscript{\textasteriskcentered} | \text{27 (17.1)%} \textsuperscript{\textasteriskcentered} | \text{26 (8.7)%} \textsuperscript{\textasteriskcentered} | \text{15 (7.1)%} \textsuperscript{\textasteriskcentered} | \text{0.011*} |
| Length of hospital stay (day)\footnote{\textsuperscript{\textasteriskcentered}} | \text{4.0 [3.0-9.0]} \textsuperscript{\textasteriskcentered} | \text{4.0 [3.0-20.0]} \textsuperscript{\textasteriskcentered} | \text{4.0 [2.0-13.0]} \textsuperscript{\textasteriskcentered} | \text{4.0 [2.0-17.0]} \textsuperscript{\textasteriskcentered} | \text{< 0.001**} |

\footnote{\textsuperscript{\textdagger}: \text{n (%)}, \text{\textsection}: mean ± standard deviation, \text{\textdagger}: median [min-max]. PEEP: positive end-expiratory pressure, RM: recruitment maneuver. *: Pearson Chi-Square veya Fisher Freeman Halton test. **: Kruskal-Wallis H test. \textsuperscript{\textasteriskcentered}: Different letters in the same row show a statistical difference. Please note the significant differences between different letters in each row.}
secondary analysis of the PROBESE trial. They used three PEEP levels: 4-5 cm H\textsubscript{2}O, 12 cm H\textsubscript{2}O with ARM, and individualized PEEP. Based on the primary outcome, that is, the PaO\textsubscript{2}/FiO\textsubscript{2} ratio, the individualized PEEP approach caused higher PEEP (median 18 mm Hg) and better oxygenation values, lower driving pressures, and redistribution of ventilation toward dependent lung areas\textsuperscript{1}. In this way, further reduction of atelectasis development in dependent lung areas was achieved in obese patients who underwent laparoscopic bariatric surgery\textsuperscript{1,4}. The PEEP levels above 12 cm H\textsubscript{2}O reportedly led to higher ventilation of the dependent lung with individualized and consecutively higher PEEP levels\textsuperscript{1}.

Nonetheless, it was reported\textsuperscript{4} that individualized and higher PEEP did not prevent the re-occurrence of atelectasis in morbidly obese patients with elective laparoscopic surgery and was thus not beneficial. Simon et al\textsuperscript{1} concluded that ARM followed by a high PEEP of 12 cm H\textsubscript{2}O was insufficient to recruit the lung in some patients. They suggested that higher PEEP with ARM is a safe and effective strategy to ventilate obese patients during surgical treatment\textsuperscript{1}. The relevant findings of this study are consistent with the respective findings reported in the literature.

The patients with a PEEP of 10 cm H\textsubscript{2}O had significantly higher PaO\textsubscript{2}/FiO\textsubscript{2} ratios than those with a PEEP of 5 cm H\textsubscript{2}O in this study. Additionally, the rates of postoperative atelectasis were found to be significantly lower in patients in the groups with a PEEP value of 10 cm H\textsubscript{2}O, either with or without ARM. Using PEEP of 10 cm H\textsubscript{2}O combined with ARM might be more beneficial in obese patients.

Limitations of the Study

The retrospective design of the study was its primary limitation. A prospectively held database was used in this study; however, the reliability of the data might pose some concerns. Additionally, some of the data might have been missed while gathering the data retrospectively.

Conclusions

The study findings revealed that an intraoperative respiratory management strategy featuring ARM with a PEEP level of at least 10 cm H\textsubscript{2}O significantly improved the intraoperative respiratory parameters, causing a significant reduction in the rate of postoperative atelectasis.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Authors’ Contribution

Aslı Mete Yıldız: Conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software. Gökhan Kilinç: Data curation, project administration. Hülya Sungurtekin: Supervision, validation, visualization, roles/writing- original draft. Simay Karaduman: Writing- review and editing. Onur Birsen: Investigation, methodology, project administration.

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Availability of Data and Materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Informed Consent

Written informed consent could not be obtained from the patients due to the study’s retrospective design and the data’s unanimity.

Ethics Approval

The study protocol was approved by the Pamukkale University Local Ethic Committee (Decision number: 60116787-020-296902 and date 17.07.2019). The study was carried out in accordance with the principles set forth in the Declaration of Helsinki.

References


