The effect of alveolar recruitment maneuver and positive end expiratory pressure on arterial oxygenation and postoperative outcome in morbidly obese patients undergoing laparoscopic reduction gastroplasty

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Objective
The aim of this work was to study the effect of the alveolar recruitment maneuver followed by positive end expiratory pressure on gas exchange in morbidly obese patients undergoing laparoscopic reduction gastroplasty and to study its effect on postoperative patient outcome.

Patients and methods
This prospective controlled randomized clinical trial was conducted on 40 patients with BMI greater than 40 kg/m^2 who underwent laparoscopic reduction gastroplasty under general anesthesia. The patients were allocated randomly into two equal groups: group I (the control group) included patients whose lungs were ventilated using the standard method and group II (the study group) included patients whose lungs were ventilated as in group I and for whom the lung recruitment maneuver was then performed by inflating the lungs with a positive pressure of 40 cmH2O, maintaining this pressure for 15 s, followed by positive end expiratory pressure of 8 cmH2O. This was repeated every 10 min throughout the procedure until extubation in the ICU. At the end of the surgery, all patients were transferred intubated to the ICU until extubation and then transferred to the intermediate care unit for 24 postoperative hours. Volume of arterial blood gases, mean arterial blood pressure, heart rate, operative time, time to extubation, duration of ICU stay, and the number of patients in need of postextubation ventilatory support were recorded throughout the study.

Results
Hemodynamic variables showed no significant difference between the groups. PaO2 showed a highly significant increase in both groups after intubation, but increase in PaO2 was more significant in group II than in group I. PaCO2 and pH showed no significant difference between groups. There was a significant decrease in extubation time and duration of ICU stay in group II patients in comparison with group I. As regards the postextubation ventilatory support, only one patient in group II needed a postextubation continuous positive airway pressure mask for 1 h, whereas in group I four patients needed a postextubation continuous positive airway pressure mask and one of them required reintubation.

Conclusion
Lung recruitment maneuver is a suitable and beneficial technique during recovery in morbidly obese patients with minimal side effects. It is also beneficial in decreasing the time to extubation and duration of ICU stay.

Keywords:
alveolar recruitment, laparoscopic reduction gastroplasty, morbidly obese patients

Introduction
Abnormalities in gas exchange that occur during anesthesia are mostly caused by atelectasis, and these abnormalities are exaggerated in morbidly obese patients. There is a direct relationship between this exaggeration and BMI [1]. Under anesthesia, the closing volume of morbidly obese patients can exceed their functional residual capacity, causing airway closure and resulting in an increase in intrapulmonary shunt, which leads to an increased alveolar-arterial oxygen tension gradient [2]. With the occurrence of pneumoperitonium during laparoscopy there are decreases in thoracopulmonary compliance by 30–50% in healthy [3] and obese patients [4], further reduction in functional residual capacity [5], elevation of the diaphragm, and pulmonary ventilation perfusion mismatching [6]. However, increasing intra-abdominal pressure to 14 mmHg with the
patient in a 10–20° head-up or head-down position does not significantly modify the physiological dead space or shunt in patients without cardiovascular problems [7]. There are various ventilatory strategies to improve gas exchange during bariatric surgery. Sprung et al. [8] used large tidal volumes and the respiratory rate to shift the mean lung volume above the closing volume to increase the arterial O₂ tension (PaO₂). In addition, Pelosi et al. [9] tried to apply positive end expiratory pressure (PEEP) alone in obese patients and found that there was a modest increase in PaO₂. Rothen et al. [10] recommended the alveolar recruitment maneuver. This maneuver reopens the atelectatic lung areas during anesthesia by sustained inspiratory pressure of at least 40 cmH₂O, maintaining this pressure for 10–15 s [11]. This maneuver was shown to be more effective in prevention of recurrence of atelectasis, especially if followed by PEEP [12]. Although this technique effectively improves the gas exchange in morbidly obese patients throughout the course of the operation, it promptly dissipates after tracheal extubation [1]. This study aimed to study the effect of the alveolar recruitment maneuver followed by PEEP on gas exchange in morbidly obese patients undergoing laparoscopic reduction gastroplasty and study its effect on the postoperative patient outcome.

**Patients and methods**

After obtaining approval from the institutional ethical committee and written informed consent from the patients, this prospective controlled randomized clinical trial was conducted on 40 patients who were ASA I or II, aged between 23 and 59 years, nonsmokers, with a BMI greater than 40 kg/m² who underwent laparoscopic reduction gastroplasty.

Patients with preoperative pulmonary disease, cardiac problems, liver or renal impairment, neurological disorders and with blood hemoglobin level less than 12 g/dl were excluded from the study.

All patients were premedicated with 0.1 mg/kg midazolam. After preoxygenation, general anesthesia was induced with 2 mg/kg propofol, 2 μg/kg fentanyl, and 1.5 mg/kg succinylcholine. After oral endotracheal intubation with a reinforced endotracheal tube size of 7.5 mm ID, anesthesia was maintained with 1–2 minimum alveolar concentration sevoflurane and fentanyl 1–2 μg/kg/h over the period of the operation. Neuromuscular blockade was obtained using rocuronium bromide 0.8 mg/kg as the bolus dose and 10 μg/kg/min as the maintenance dose. Intraoperative monitoring was done using 5-lead ECG, pulse oxymetry, capnography, urine output, and invasive blood pressure. All patients were mechanically ventilated with a tidal volume of 10 ml/kg, respiratory rate 12/min, I: E ratio = 1 : 2, and FiO₂ 100%. Ventilation was adjusted to maintain end tidal CO₂ between 35 and 40 mmHg. All medications and parameters were calculated on an ideal body weight basis.

Patients were randomly allocated using closed envelopes into two equal groups:

- **Group I** (the control group): the patient’s lungs were ventilated using the standard method mentioned above.
- **Group II** (the study group): the patient’s lungs were ventilated in the same manner as in group I. After the creation of pneumoperitonium, the lung recruitment maneuver was performed by inflating the lungs with a positive pressure of 40 cmH₂O, maintaining this pressure for 15 s, followed by PEEP of 8 cmH₂O. This was repeated every 10 min throughout the procedure and postoperatively until extubation in the ICU.

Fluid and blood loss was calculated and replaced as appropriate. Urine output was maintained above 0.5 ml/kg/h. Hemodynamic variables (heart rate and mean arterial blood pressure) were maintained within 20% of the preoperative level. Surgical procedures were carried out by the same surgical team.

At the end of surgery, all anesthetics were stopped and the patients were transferred intubated to the ICU under sedation with dexmedetomidine 0.2 μg/kg/h until extubation and then transferred to the intermediate care unit for 24 postoperative hours.

Volume of arterial blood gases (PaO₂, PaCO₂, and pH), mean arterial blood pressure, and heart rate were recorded for all patients at the following intervals:

1. **Before induction of anesthesia.**
2. **After intubation and before application of the recruitment maneuver.**
3. **Ten minutes after application of the first recruitment maneuver.**
4. **At the end of surgery.**
5. **When the patient reach the ICU.**
6. **Every 30 min until extubation.**

The following parameters were recorded:

1. **Operative time (min):** this is the time from skin incision until closure of the wound.
2. **Time to extubation (min):** this is the time from intubation until extubation in the ICU.
3. **Duration of ICU stay (h):** this is the time from admission into the ICU until discharge.
4. **The number of patients in need of postextubation ventilatory support in the form of continuous positive airway pressure (CPAP) mask or reintubation.**

Weaning from mechanical ventilation was performed using gradual reduction of pressure support. Weaning was started once the patient was clinically stable and met the following criteria:

1. Normal sensorium.
2. PaO₂ ≥ 60 mmHg at a FiO₂ ≤ 40% with an external PEEP ≤ 5 cmH₂O.
3. No cardiac ischemia or arrhythmias.

One hour after successful extubation, the volume of arterial blood gases was recorded again. Ventilatory...
support in the form of a CPAP mask was given for 1 h if the patients met at least one of the following criteria:

1. Respiratory acidosis.
2. pH < 7.35 with a PaCO₂ > 45 mmHg.
3. Increase in PaCO₂ > 15%.
4. Hypoxemia (SaO₂ < 90% for FiO₂ > 50%).

Noninvasive ventilatory support was given and the respiratory pressure was adjusted according to the patient’s tolerance, with external PEEP of less than 6 cmH₂O, aiming to achieve a respiratory rate of less than 25 breaths/min and arterial O₂ saturation greater than 92%, with pH greater than 7.35.

If noninvasive ventilation failed to achieve the aim, the patients were reintubated.

Criteria for ICU discharge were as follows: (a) hemodynamic stability, (b) level of consciousness sufficient to protect the airway, (c) urinary output of at least 0.5 ml/kg/h, and postextubation respiratory adequacy with maintenance of SaO₂ greater than 95%.

Statistical analysis

Statistical analysis was performed using SPSS version 17 (SPSS Inc., Chicago, Illinois, USA). All data are presented as mean and SD. All parameters were analyzed using the Student t-test, except for analysis of sex, which was carried out using the χ²-test. A P-value less than 0.05 was considered statistically significant.

Results

Demographic characteristics showed a nonsignificant difference between groups as regards age, sex, BMI, and operative time (Table 1).

Hemodynamic variables showed no significant difference between groups as regards the mean arterial blood pressure (Fig. 1) and heart rate (Fig. 2).

PaO₂ showed a highly significant increase in both groups after intubation, but increase in PaO₂ was more significant in group II than in group I throughout the operation until extubation (Fig. 3).

PaCO₂ (Fig. 4) and pH (Fig. 5) showed no significant difference between groups.
There was a significant decrease in extubation time and duration of ICU stay in group II in comparison with group I (Table 2).

As regards the postextubation ventilatory support, only one patient in group II needed a postextubation CPAP mask for 1 h, whereas in group I four patients needed a postextubation CPAP mask and one required reintubation.

**Discussion**

This study documented that the alveolar recruitment maneuver with PEEP improved intraoperative gas exchange with minimal side effects and can be continued postoperatively in the ICU. It was beneficial in decreasing the time to extubation and duration of ICU stay and reduced the need for postoperative ventilatory support. The efficiency of PEEP alone in providing enough transmural pressure to inflate the collapsed alveoli is limited and it may be associated with overstretching of already opened alveoli and redistribution of pulmonary blood flow toward nonventilated alveoli [13]. Thesese consequences may partially offset the beneficial effects of PEEP on lung volume and small airway closure [14]. The application of the recruitment maneuver in the present study significantly accelerated and magnified the beneficial effects of PEEP by providing a sustained high peak inspiratory pressure. The alveolar recruitment maneuver overcame the opening pressure of the collapsed alveoli and accelerated the recruitment of atelectatic areas, leading to increased ventilation perfusion ratio and decreased shunt fraction. These results are in agreement with those of Chalhoub et al. [15] who studied the effect of the alveolar recruitment maneuver on arterial oxygenation in morbidly obese patients undergoing open bariatric surgery and documented an improvement. Further, Turman et al. [16] reported that an alveolar recruitment maneuver increased the respiratory system compliance in patients of average weight. Similar results were recorded by Whalen et al. [1] during laparoscopic bariatric surgery. They suggested that alveolar recruitment is an effective mode of improving intraoperative oxygenation in morbidly obese patients and showed that the effect was short lived and associated with the frequent use of intraoperative vasopressors because of hemodynamic instability. The present study reported hemodynamic stability throughout the study because of the application of small PEEP (8 cmH₂O) in comparison with 12 cmH₂O PEEP used by Francis and colleagues. To our knowledge, there are no other studies on the postoperative effect of alveolar recruitment on patient outcome after anesthesia.

**Conclusion**

The lung recruitment maneuver with PEEP is a suitable and beneficial technique during recovery in morbidly obese patients with minimal side effects. It is also beneficial in decreasing the time to extubation and duration of ICU stay.

**Acknowledgements**

**Conflicts of interest**

There are no conflicts of interest.

**References**
