EFFECT OF ALVEOLAR RECRUITMENT ON OXYGENATION AND CARBON DIOXIDE ELIMINATION DURING LAPAROSCOPIC BARIATRIC SURGERY AND COMPARISON WITH PRESSURE CONTROLLED AND VOLUME CONTROLLED VENTILATION

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ABSTRACT

BACKGROUND

Arterial oxygenation is inversely proportional to body mass index (BMI) in morbidly obese individuals. Alveolar recruitment maneuver consists of sustained insufflations, mainly with the use of positive end expiratory pressure (PEEP). We investigated the effects of alveolar recruitment on arterial oxygenation and carbon dioxide (CO₂) elimination and compared the same with volume-controlled and pressure-controlled ventilation during laparoscopic sleeve gastrectomy in morbidly obese patients.

MATERIALS AND METHODS

In this prospective randomized study, thirty morbidly obese patients with BMI >35 kg/m², American Society of Anesthesiologists (ASA) grade I and II between 18 and 60 years scheduled for laparoscopic sleeve gastrectomy under general anesthesia were included. They were randomly allocated into three groups of ten each using sealed envelope method. Group P received pressure controlled ventilation; group V received volume controlled ventilation. In group R, alveolar recruitment maneuver was performed at 10 minutes after creation of pneumoperitoneum, by increasing the PEEP in a stepwise manner – initially to 10 cm H₂O for 3 breaths, then to 15 cm H₂O for 3 breaths and finally to 20 cm H₂O for 10 breaths and then PEEP was maintained at 12 cm H₂O.

RESULTS

In the recruitment group, PaO₂ at five minutes after recruitment was significantly higher than PaO₂ at 5 minutes after intubation (P<0.005). However, there was no significant difference in the mean PaO₂ and PaCO₂ on comparing the three groups.

CONCLUSION

Our study showed that alveolar recruitment maneuver effectively improves oxygenation and this beneficial effect is transient. There was no significant difference in PaO₂ and PaCO₂ when recruitment maneuver was compared with both volume controlled and pressure controlled ventilation. Both volume control and pressure control ventilation can be utilized during laparoscopic bariatric surgery. Alveolar recruitment can be considered whenever an improvement in oxygenation is sought.

KEYWORDS

Morbid Obesity, Oxygenation, Alveolar Recruitment, PEEP.

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BACKGROUND

Morbid obesity results in several pathophysiologic changes of the respiratory system mechanics that promote the development of intraoperative atelectasis and exaggerate the impairment of gas exchange. Obesity is considered as independent risk factor for respiratory complications. It has been reported that arterial oxygenation is inversely related to body mass index (BMI).¹

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Maintenance of adequate ventilation and oxygenation is often a major problem in obese patients during general anaesthesia. The incidence of atelectasis is high in obese patients during general anaesthesia and immediate postoperative period compared to non-obese individuals.²

Different ventilatory strategies have been described for obese patients to expand the collapsed alveoli. Large tidal volume (V_T) up to 20 ml/kg does not improve PaO₂ in morbidly obese and may promote lung injury.³

Pressure controlled ventilation (PCV) uses a decelerating flow which produces high initial flow rate resulting in more rapid inflation of alveoli. The homogeneous distribution of ventilation produced by volume controlled ventilation (VCV) leads to improvement in ventilation perfusion matching.⁴

A number of studies suggested that alveolar recruitment is beneficial in opening atelectatic lung areas present during anesthesia and to improve arterial oxygenation. Alveolar recruitment maneuver consists of sustained insufflations, mainly with the use of positive end-expiratory pressure (PEEP).² The application of high inspiratory pressure causes expansion of collapsed alveoli and increases the PaO₂.

Though there are various types of recruitment, irrespective of the mechanism, alveolar recruitment was found to improve oxygenation, ventilatory mechanics and the repair of damage to the lung epithelium.⁵

In our study, we evaluated the effect of alveolar recruitment on oxygenation and CO₂ elimination during laparoscopic sleeve gastrectomy in morbidly obese patients. We also compared alveolar recruitment with the conventional pressure controlled ventilation and volume controlled ventilation in terms of arterial oxygenation and CO₂ elimination.

MATERIALS AND METHODS

This study was a prospective, randomized, single centre study conducted in the Department of Anaesthesiology and Intensive care at All India Institute of Medical Sciences, New Delhi from August 2009 to February 2011. After institutional ethics committee approval and consent, 30 patients with BMI >35 kg/m² between 18 and 60 years of both sexes scheduled for laparoscopic bariatric surgery were included in the study. Patients having major obstructive or restrictive respiratory disorder with a baseline PaCO₂ > 60 mm Hg were excluded from the study. The patients were randomly assigned to one of the three groups, randomization done by using a sealed envelope method. Each group consisted of ten patients. Group V received VCV, group P received PCV and group R received alveolar recruitment.

Anaesthetic management was standardized as follows. After the patients were transferred to the operating room, standard monitors (ECG, non-invasive blood pressure and pulse oximetry) were attached. After preoxygenation, anaesthesia was induced with 2 mg/kg ideal body weight (IBW) of Propofol, supplemented by Fentanyl 2 µg/kg of lean body weight. Tracheal intubation was performed with appropriate sized endotracheal tube facilitated by 1.5 mg/kg total body weight of Succinylcholine. After intubation, radial artery was cannulated for invasive BP monitoring and intermittent arterial blood gas analysis.

In group V, the ventilatory settings were made as follows; tidal volume (V_T) of 8 ml/kg IBW, respiratory rate (RR) of 12 breaths/min, inspiratory; expiratory ratio (I: E) of 1:2, positive end expiratory pressure (PEEP) of 5 cm H₂O. End tidal CO₂ (EtCO₂) was adjusted to 40-48 mm Hg by increasing the RR by 2 breaths/min (every 5 min till 18 breaths/min) and then V_T was increased by 1 ml/kg till 12 ml/kg or peak airway pressure (P_{peak}) of 40 cm H₂O. If the target EtCO₂ was not achieved, then RR was increased to 25/min with a maximum peak airway pressure (P_{peak}) of 40 cm H₂O.

In group P, patient's lungs were ventilated with a peak inspiratory pressure to deliver a VT of 8 ml/kg IBW, RR of 12 breaths/min, I:E ratio of 1:2, PEEP of 5 cm H₂O. A target EtCO₂ of 40-48 mm Hg was maintained and if not achieved, then respiratory rate was increased by 2 breaths/min (every 5 min, till 18 breaths/min). If target EtCO₂ was still not achieved, then P_{peak} was increased by 2 cm H₂O increments till a maximum of 40 cm H₂O. If the target EtCO₂ was still not achieved, then RR was increased by 2 breaths/min to a maximum of 25 breaths/min.

In group R, the ventilatory settings were made as follows; V_T of 8 ml/kg IBW, RR of 12 breaths/min, I: E of 1:2, PEEP of 5 cm H₂O. EtCO₂ was maintained at 40-48 mm Hg by increasing the RR by 2 breaths/min (every 5 min till 18

breaths/min) and then V_T was increased by 1 ml/kg till 12 ml/kg or peak airway pressure (P_{peak}) of 40 cm H₂O. Lung recruitment manoeuvre was performed at 10 minutes after creation of pneumoperitoneum, by increasing the PEEP in a stepwise manner – initially to 10 cm H₂O for 3 breaths, then to 15 cm H₂O for 3 breaths and finally to 20 cm H₂O for 10 breaths and then PEEP was maintained at 12 cm H₂O. If at any point during the recruitment manoeuvre P_{peak} exceeded 40 cm H₂O, the next level of PEEP was discontinued.

Anaesthesia was maintained with a mixture of oxygen and air (FiO₂-0.5) and isoflurane. Neuromuscular blockade was maintained with Atracurium boluses. All patients were stabilized in the reverse Trendelenburg position. The intra-abdominal pressure was maintained between 14-17 mm of Hg. Intra operative analgesia was supplemented with Paracetamol 1 gm intravenously and boluses of Fentanyl.

Parameters such as oxygen saturation (SpO₂), EtCO₂ and arterial blood gases (ABG) were measured. Baseline measurement was recorded at 5 min after intubation, second measurement at 5 min after creating pneumoperitoneum, and then every 15 minutes till the release of pneumoperitoneum. Postoperatively O₂ requirement in hours, SpO₂ and ABG were recorded.

Statistical Analysis

Statistical analysis was carried out using SPSS software. Data were presented as mean ± standard deviation (SD). The demographic parameters, SpO₂, EtCO₂ and ABG were analysed using one way ANOVA test. P < 0.05 was considered significant and P > 0.05 not significant.

RESULTS

The demographic parameters such as age, sex, actual weight, ideal weight, height, BMI and comorbidities of the patients did not show any significant difference among the groups. The room air arterial blood gas analyses (pH, PaO₂, PaCO₂) were comparable in all the 3 groups.

There is no statistical significance in the intraoperative SpO₂ and EtCO₂ values among the three groups. The intraoperative mean PaO₂ and PaCO₂ values are shown in tables 1 and 2 respectively and represented graphically in figures 1 and 2 respectively. There is no statistical significance in the ABG values among the three groups.

Time (Minutes)	Group V Mean (±SD)	Group P Mean (±SD)	Group R Mean (±SD)	p Value
Baseline	159.7 (±95.63)	132.4 (±58.82)	115.8 (±20.2)	0.337
5 min	134.4 (±41.47)	130.4 (±39.95)	116.7 (±19.83)	0.507
15 min	123.8 (±25.62)	128.1 (±36.29)	132.5 (±26.95)	0.812
30 min	122.7 (±31.38)	122.9 (±32.73)	122.2 (±27.57)	0.999
60 min	123.3 (±28.49)	127.5 (±30.87)	123.8 (±29.02)	0.941

Table 1. Intraoperative PaO₂

PaO₂- partial pressure of oxygen in arterial blood. SD- standard deviation.

Figure 1. Intraoperative PaO₂ changes in the three groups

PaCO ₂ (mm Hg)	Group V Mean (±SD)	Group P Mean (±SD)	Group R Mean (±SD)	p value
Baseline	39.10 (±2.96)	36.10 (±4.40)	36.4 (±4.16)	0.185
5 min	39.6 (±4.52)	38.6 (±4.03)	37.6 (±5.4)	0.639
15 min	39.5 (±2.99)	39.1 (±3.98)	38.3 (±5.03)	0.801
30 min	40.10 (±5.13)	38.7 (±4.96)	39.6 (±6)	0.842
60 min	41.10 (±5.40)	39.6 (±6.27)	39.7 (±5.45)	0.808

Table 2. Intraoperative PaCO₂

PaCO₂: partial pressure of oxygen in arterial blood

Figure 2. Intraoperative PaCO₂ changes in the three groups

Alveolar Recruitment

In group R, ten minutes after pneumoperitoneum alveolar recruitment was carried out by increasing PEEP in increments of 10, 15 cm H₂O (3 breaths each) and 20 cm H₂O (10 breaths). Alveolar recruitment was possible in only 6 out of 10 patients, as in the remaining 4 patients P_{peak} raised to more than 40 cm H₂O. Airway pressures, SpO₂, EtCO₂ and ABG were recorded 5 minutes after recruitment. By repeated measures analysis followed by post hoc analysis by least square deviation method, we found that PaO₂ at 5 min after recruitment [132.5 (±26.9)] was significantly higher than PaO₂ at 5 minutes after intubation [115.8 (±20.2) p=0.024] and at 5 minutes after pneumoperitoneum [116.7 (±19.8) p=0.001]. PaCO₂ and pH at 5 minutes after recruitment was comparable with PaCO₂ at specific time intervals.

There is no difference in the SpO₂ among the three groups. The postoperative arterial blood gas analysis was done in all groups at 60 and 120 minutes postoperatively and they were comparable between the groups as shown in table 3.

Postoperative ABG		Group V (Mean±SD)	Group P (Mean±SD)	Group R (Mean±SD)	p value
pH	At 60 min	7.36±0.02	7.34±0.18	7.33±0.018	0.063
	At 120 min	7.35±0.03	7.35±0.02	7.35±0.03	0.988
PaO ₂ (mm Hg)	At 60 min	103.3±16.4	104.6±18.8	103.7±11.7	0.983
	At 120 min	98.3±12.4	100±14.7	98.1±9.9	0.933
PaCO ₂ (mm Hg)	At 60 min	40.8±5.1	41.2±7.1	41±7.2	0.991
	At 120 min	40±4.5	38.9±6	39.3±5.7	0.901

Table 3. Postoperative arterial blood gases (ABG)

Table 3. Postoperative arterial blood gases (ABG)

DISCUSSION

According to the 1991 National Institutes of Health (NIH) consensus conference on gastrointestinal surgery for severe obesity, patients are candidates for bariatric surgery if they are morbidly obese (BMI >40 kg/m² or ≥ 35 kg/m² with comorbidities), have failed attempts at diet and exercise, are motivated and well informed, and are free of significant psychological disease.⁶ All the patients scheduled for laparoscopic bariatric surgery in our study fulfilled the above criteria.

Increasing levels of BMI is significantly associated with decreasing PaO₂ and increasing PaCO₂.⁷ Pneumoperitoneum and systemic resorption of CO₂ associated with laparoscopic surgery may further impact oxygenation in the obese. Reduction in arterial oxygenation during anaesthesia has been seen to be greater in obese compared with lean patients and this is directly related to the increase in BMI. Morbid obesity can cause a restrictive lung syndrome with reduction in lung volumes, expiratory reserve volume and functional residual capacity (FRC) due to restricted thoracic wall movement, decreased lung compliance and increased airway resistance. These factors along with general anaesthesia may cause alveolar collapse and ventilation/perfusion mismatching leading to impaired oxygenation.

Various ventilatory strategies have been proposed to improve gas exchange during general anaesthesia in morbidly obese patients. We compared alveolar recruitment manoeuvre with the conventional modes of ventilation to find out whether alveolar recruitment has a beneficial effect on oxygenation and CO₂ removal.

In several studies, alveolar recruitment during bariatric surgery has been found to be beneficial on gas exchange and respiratory mechanics and this effect is maintained on repeating the manoeuvre.^{8,9} There are no specific recommendations regarding recruitment manoeuvres due to high heterogeneity in the delivery methods of recruitment manoeuvres. In our study, we performed lung recruitment manoeuvre at 10 minutes after creation of pneumoperitoneum, by increasing the PEEP in a stepwise manner. Initially we increased the PEEP to 10 cm H₂O for 3 breaths, then to 15 cm H₂O for 3 breaths and finally to 20 cm H₂O for 10 breaths. The recruitment manoeuvre done in our study was similar to the manoeuvre which was done in Whalen's study.⁸ However we did a single recruitment manoeuvre and studied whether the beneficial effect of recruitment if any was sustained. Talab et al demonstrated

that alveolar recruitment manoeuvre is effective only if it is followed by PEEP adequate enough to maintain the recruited alveoli.¹⁰ Therefore in our study, after alveolar recruitment manoeuvre we maintained a PEEP of 12 cm H₂O to maintain the recruited alveoli. Literature shows that pressure controlled ventilation is more effective in improving oxygenation and CO₂ elimination in morbidly obese individuals.¹⁰ This prompted us to include pressure controlled ventilation in our study. Also, there are limited studies comparing the efficacy of alveolar recruitment with the commonly used intraoperative ventilatory strategies such as pressure control and volume control ventilation during laparoscopic bariatric surgery.

Our study showed that, in the recruitment group, PaO₂ at 5 min after recruitment [132.5(±26.9)] was significantly higher than PaO₂ at 5 minutes after intubation [115.8(±20.2) p=0.024] and at 5 minutes after pneumoperitoneum [116.7(±19.8) p=0.001]. In the postoperative period, at 60 minutes PaO₂ was 103.7±11.7 mm Hg in the recruitment group and 98.3±12.4 at 120 minutes (p> 0.05). This showed that the benefit of a single recruitment manoeuvre was transient and the benefit on arterial oxygenation did not sustained during the intraoperative and postoperative period. Alveolar recruitment manoeuvre did not had any effect on PaCO₂ levels in our study in contrary to the Whalen et al study, where recruitment lead to significant increase in PaCO₂ levels.⁸

Our study results were different with the study conducted by Ahmed et al during laparoscopic bariatric surgery, in which they compared conventionally ventilated group with a group receiving alveolar recruitment with a PEEP of 40 cm H₂O and a third group receiving alveolar recruitment manoeuvre repeated 30 and 90 minutes after surgery with both recruitment groups receiving PEEP of 10 cm H₂O till the end of the procedure. They found that alveolar recruitment improved gas exchange and repeated manoeuvres maintained adequate gas exchange and lead to better compliance.⁹ In our study, though the arterial oxygenation improved temporarily after alveolar recruitment, there was no significant difference in arterial oxygenation and CO₂ removal in between the three groups.

Our study design was similar to that of Whalen et al. However, we compared the recruitment group with the conventional intraoperative modes such as volume controlled and pressure controlled ventilation unlike the study done by Whalen et al, in which they compared the recruitment group with only volume controlled ventilation. Whalen et al divided 20 patients into two groups; in recruitment group PEEP was increased in stepwise fashion of 10-15-20 cm H₂O, not to exceed P_{peak} of 50 cm H₂O and then PEEP set at 12 cm H₂O, whereas control group received PEEP of 4 cm H₂O. They found that recruitment group had a significantly higher intraoperative PaO₂/FiO₂ ratio and dynamic compliance compared to the control group throughout the course of operation, but it promptly dissipated after tracheal extubation.⁸

Previous studies stated that the rationale for the recruitment manoeuvre is based on the fact that sustained, high airway pressures are required to resolve atelectasis in experimental models.¹¹ This beneficial effect of alveolar

recruitment on atelectasis in morbidly obese individuals was demonstrated through computed tomography images.¹²

VCV utilizes a constant flow to deliver a target tidal volume and thus ensure satisfactory minute ventilation.⁴ However PCV uses a decelerating flow which reaches the highest possible value at the beginning of inspiration, while having a preset pressure limitation but minimum tidal volume. Flow diminishes throughout inspiration according to target pressure and resulting tidal volume depends on pressure limitation and chest compliance.⁴ Varying observations have been made with respect to oxygenation and carbon dioxide elimination in studies comparing ventilatory modes in patients undergoing bariatric surgery. In our study, there is no significant difference (p>0.05) in both PaO₂ and PaCO₂ between the VCV and PCV groups. Thereby our study inferred that both volume control and pressure control ventilation can be utilized during laparoscopic bariatric surgery. This is in agreement with the findings of Hans et al who compared PCV and VCV in 40 obese patients scheduled for gastric bypass surgery and found that PaO₂ and PaCO₂ were comparable between the groups.¹³ Our study was in contrary to the observation made by Cadi et al, where they found that intra-operative PaO₂ in PCV group was significantly higher than group VCV during laparoscopic gastric binding in morbidly obese.¹⁰ Whereas in a study done by De Baerdemaeker et al during laparoscopic gastric banding, they found that though arterial oxygenation was comparable between the VCV and PCV groups, CO₂ elimination was better with pressure controlled ventilation.¹⁴

This study has shown that though alveolar recruitment manoeuvre improves arterial oxygenation during laparoscopic bariatric surgery, there was no significant difference in PaO₂ and PaCO₂ when compared with both volume controlled and pressure controlled ventilation. The lack of significance may be due to the small sample size and further studies with large number of patients are required.

CONCLUSION

We found that alveolar recruitment leads to temporary improvement in oxygenation during laparoscopic sleeve gastrectomy in morbidly obese individuals and recruitment must be individualized to obtain maximum benefit. Repeated recruitment manoeuvres may be done to sustain the benefit achieved in arterial oxygenation. Our study also showed that recruitment manoeuvre did not affect the carbon dioxide elimination. Also, we inferred that, on comparing alveolar recruitment manoeuvre with the conventional pressure controlled ventilation and volume controlled ventilation, there was no significant difference in arterial oxygenation and CO₂ elimination (p>0.05). Alveolar recruitment manoeuvre may be considered whenever an improvement in arterial oxygenation is required during laparoscopic bariatric surgery in morbidly obese patients.

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