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# Comparative study between volume-controlled ventilation and pressure-controlled ventilation in prevention of postoperative pulmonary atelectasis in morbidly obese patients undergoing laparoscopic gastric sleeve surgery

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## Abstract

**Background:** Atelectasis can result during general anesthesia from mechanical ventilation and decrease in lung volume particularly in morbidly obese patients undergoing abdominal laparoscopic sleeve surgery, which may result in the development of postoperative pulmonary complications (PPCs), including hypoxemia and pneumonia, with an increased risk of postoperative morbidity and mortality.

**Objective:** To compare between volume-controlled ventilation (VCV) and pressure-controlled ventilation (PCV) in prevention of postoperative pulmonary atelectasis in morbidly obese patients undergoing laparoscopic gastric sleeve surgery.

**Methods:** This is a randomized prospective comparative clinical study with a total of 52 morbidly obese patients who were randomly divided into 2 groups; 26 patients in group (M) for VCV and 26 in group (P) for PCV arterial blood samples were obtained, and PaCO<sub>2</sub>, PaO<sub>2</sub>, and SaO<sub>2</sub> were obtained and recorded. ABG analyses were also obtained 30 min, 12 h, and 24 h post-extubation, and PaCO<sub>2</sub>, PaO<sub>2</sub>, and SaO<sub>2</sub> were obtained and recorded.

**Results:** The results of this study revealed no significant differences between PCV and VCV as regards the incidence of postoperative lung atelectasis immediately postoperative (69.2% with VCV vs 61.5% with PCV,  $p = 0.368$ ), 12 h postoperative (61.5% with VCV vs 53.8% with PCV,  $p = 0.282$ ), and 24 h postoperative (53.8% with VCV vs 46.2% with PCV,  $p = 0.325$ ). There were also no significant differences between VCV and PCV as regards baseline, intra-, and post-operative PaCO<sub>2</sub> levels as well as baseline and postoperative SaO<sub>2</sub> and PaO<sub>2</sub> values. However, PCV showed better intraoperative oxygenation compared to VCV. SaO<sub>2</sub> was  $96.32\% \pm 1.85$  and  $97.25\% \pm 1.37$  in VCV and PCV groups respectively ( $p = 0.027$ ) while PaO<sub>2</sub> was  $212.75 \text{ mmHg} \pm 20.13$  and  $225.8 \text{ mmHg} \pm 18.69$  in VCV and PCV groups respectively ( $p = 0.011$ ).

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**Conclusion:** Despite a slight improvement in intraoperative oxygenation parameters ( $PO_2$ ,  $SaO_2$ ) with PCV than VCV, there is no significant difference between VCV and PCV in the prevention of postoperative pulmonary atelectasis; moreover, there is no difference in postoperative oxygenation parameters in morbidly obese patients who undergo laparoscopic sleeve surgery.

**Keywords:** VCV, PCV, Atelectasis

## Introduction

Obesity is a worldwide serious problem. Obese patients are more likely than non-obese patients to develop atelectasis, which resolves more slowly. This may be attributed to marked impairment of the respiratory mechanics (decreased chest wall and lung compliance and decreased functional residual capacity) promoting airway closure with reduction of the oxygenation index ( $PaO_2/PAO_2$ ) to a greater extent than in healthy weight subjects. For these reasons, avoiding atelectasis formation in obese patients remains challenging (Eldemrashed et al. 2017).

Volume-controlled ventilation (VCV) has been widely used for general anesthesia and has the merit of a guaranteed preset tidal volume. However, it presents the risk of increased airway pressure, when pulmonary compliances change. On the contrary, pressure-controlled ventilation (PCV) has less risk of barotrauma because peak airway pressure is limited, but it cannot ensure tidal volume. During pneumoperitoneum, PCV might be advocated because of a significant increase in airway pressure after  $CO_2$  insufflation (Choi et al. 2011).

The aim of this study was to compare volume-controlled ventilation and pressure-controlled ventilation in the prevention of post-operative atelectasis (detected by lung ultrasonography and ABG) in morbidly obese patients undergoing laparoscopic gastric sleeve operation.

## Patients and methods

After institutional ethical approval, this randomized prospective controlled clinical study was carried out in Ain Shams University Hospitals during the period from March 2018 to March 2019 on 52 morbidly obese patients from both genders aged 21 years or older who were scheduled for laparoscopic gastric sleeve under general anesthesia with body mass index (BMI) of 45–60  $kg/m^2$ . A written informed consent was taken from each patient.

In addition to refusal to participate in the study, exclusion criteria included patients with severe cardiopulmonary co-morbidities or any clinical sign of cardiopulmonary disease during preoperative physical examination (such as jugular vein distension, gallop

rhythm, hepatomegaly, tibial edema, or rales on auscultation of the chest, or any abnormalities in the preoperative 12-lead electrocardiogram or chest radiograph). Patients below 21 years of age were also excluded from the study.

## Sample size justification

MedCalc® version 12.3.0.0 program “Ostend, Belgium” was used for calculations of sample size, statistical calculator based on 95% confidence interval, and power of the study 80% with  $\alpha$  error 5%. According to a previous study, Movassagi et al. (2017) showed that the  $PaO_2$  at 55 min in group VCV ( $194.67 \pm 9.42$ ) significantly decreased, and the mean of group PCV ( $207.26 \pm 9.97$ ) with  $p$  value  $< 0.001$  was highly significant with effect size of 1.298. So it can be relied upon in this study, based on this assumption, that sample size was calculated according to these values and a minimal sample size of 50 cases was enough to find such a difference. Assuming a drop-out ratio of 5%, the sample size will be 26 cases in each group (52 total).

## Anesthetic management

All patients were kept fasting 8 h preoperative; in the pre-induction room, a wide bore IV cannula G18 was inserted and monitors were attached “pulse oximetry, electrocardiogram, and non-invasive arterial blood pressure.” All patients were premedicated by giving 1–2 mg IV midazolam. Preoperative lung ultrasonography and ABG were done as basal reference.

General anesthesia was induced as Ain Shams University Hospitals OR protocol with injection of fentanyl 1  $\mu g/kg$  – 1 i.v. followed by Na Thiopental 5 mg  $kg$  – 1 i.v. Atracurium 0.5 mg  $kg$  – 1 i.v. was used to facilitate tracheal intubation. Anesthesia was maintained with oxygen and isoflurane (minimal alveolar concentration 1–1.3); all doses were calculated according to lean body weight.

Recovery was carried out after closure wound by turning off isoflurane vaporizer and increasing  $FiO_2$  to 1.0. When respiratory attempts start, neostigmine (0.05 mg/kg) and atropine (0.01 mg/kg) were given to reverse residual neuromuscular block. This was followed by fully awake extubation (fully conscious,

**Table 1** Demographic data

Demographic data	Group (V), VCV (n = 26)	Group (P), PCV (n = 26)	t/# $\chi^2$	p value
<b>Age (years)</b>				
Range	21–50	20–50	1.457	0.124
Mean $\pm$ SD	31.82 $\pm$ 7.32	30.87 $\pm$ 7.10		
<b>Gender (number, %)</b>				
Male	8 (30.8%)	7 (26.9%)	0.894	0.497
Female	18 (69.2%)	19 (73.1%)		
<b>Duration of surgery (min)</b>				
Range	90–180	90–180	0.192	0.663
Mean $\pm$ SD	143.21 $\pm$ 26.20	138.91 $\pm$ 25.42		

This table shows no statistically significant difference between groups according to demographic data  
 t independent sample t test, # $\chi^2$  chi-square test, PCV pressure-controlled ventilation, VCV volume-controlled ventilation  
 p value > 0.05 NS; \*p value < 0.05 S; \*\*p value < 0.001 HS

vitally stable, and good muscle power), and the patient was transferred to the ICU pain-free with oxygen supply, and monitored postoperative analgesia during the first 24 h postoperative was maintained by IV ketorolac amp 30 mg every 6 h.

#### Randomization

Patients were randomized based on closed envelope method into two groups based on the mode used for intra-operative ventilation.

#### Volume-controlled ventilation (group V)

The patient's lungs were ventilated in constant-flow VCV mod; tidal volume (VT) was set at 8 mL/kg, inspiratory/expiratory (I/E) ratio 1:2, and inspired oxygen concentration (FIO<sub>2</sub>) 0.6. Positive end-expiratory pressure (PEEP) was 5 cmH<sub>2</sub>O. Respiratory rate (RR) was adjusted to maintain an end-tidal CO<sub>2</sub> pressure (PETCO<sub>2</sub>) of 38  $\pm$  2 mmHg.

#### Pressure-controlled ventilation (group P)

Pressure was adjusted to achieve VT of 8 mL/kg, I/E ratio 1:2, and inspired oxygen concentration (FIO<sub>2</sub>) 0.6.

PEEP was 5 cmH<sub>2</sub>O. RR was adjusted to maintain a PETCO<sub>2</sub> of 38  $\pm$  2 mmHg.

In both groups, arterial blood gases (ABG) were obtained every hour intraoperatively to measure PaCO<sub>2</sub>, PaO<sub>2</sub>, and SaO<sub>2</sub> then 30 min, 12 h, and 24 h after extubation.

Lung ultrasound using (MYsonou 6) curved probe was performed to each group of patients immediately postoperative then 12 and 24 h post-extubation in supine position placing the probe on lateral and inferior chest wall and longitudinally. According to the systematic protocol for LUS examination (Bouhemad et al. 2015), each hemithorax was divided into anterior, lateral, and posterior regions using anterior and posterior axillary lines as anatomic landmarks, and each region was further divided into two parts superior and inferior. Using a curved probe, detecting lung pulse, absence of A lines, and presence of B lines was used to detect atelectasis (Bouhemad et al. 2015).

The primary study outcome was postoperative pulmonary atelectasis detected by lung ultrasonography and ABG. Comparisons were also done between both groups as regards demographic data, duration of

**Table 2** PaO<sub>2</sub> (mmHg)

PaO <sub>2</sub>	Group (V), VCV (n = 26)	Group (P), PCV (n = 26)	t test	p value
<b>Preoperative</b>	86.53 $\pm$ 10.21	86.86 $\pm$ 8.41	1.316	0.134
<b>Intraoperative</b>	212.75 $\pm$ 20.13	225.85 $\pm$ 18.69	4.638	0.011*
<b>30 min after extubation</b>	82.52 $\pm$ 8.16	86.60 $\pm$ 14.42	0.823	0.346
<b>12 h after extubation</b>	86.55 $\pm$ 7.82	83.06 $\pm$ 14.24	1.108	0.272
<b>24 h after extubation</b>	87.76 $\pm$ 9.12	82.83 $\pm$ 13.93	1.176	0.166

This table shows statistically significant increase in intraoperative arterial oxygen tension (PaO<sub>2</sub>) in the PCV group compared to the VCV group  
 t independent sample t test, PCV pressure-controlled ventilation, VCV volume-controlled ventilation  
 p value > 0.05 NS, \*p value < 0.05 S

**Table 3** SaO<sub>2</sub> (%)

SaO <sub>2</sub>	Group (V), VCV (n = 26)	Group (P) PCV, (n = 26)	t test	p value
<b>Preoperative</b>	96.94 ± 1.45	97.35 ± 1.37	1.516	0.155
<b>Intraoperative</b>	96.32 ± 1.85	97.25 ± 1.37	2.384	0.027*
<b>30 min after extubation</b>	96.64 ± 1.45	97.18 ± 1.45	0.489	0.581
<b>12 h after extubation</b>	96.29 ± 2.71	96.89 ± 2.48	0.267	0.729
<b>24 h after extubation</b>	96.35 ± 2.29	97.21 ± 2.33	0.510	0.563

This table shows statistically significant increase in intraoperative arterial oxygen saturation in group P compared to group V  
t independent sample t test, PCV pressure-controlled ventilation, VCV volume-controlled ventilation  
p value > 0.05 NS; \*p value < 0.05 S

surgery, PaO<sub>2</sub>, SaO<sub>2</sub>, and PaCO<sub>2</sub> (mean intraoperative values then 30 min, 12 h, and 24 h postoperative).

### Statistical analysis

Recorded data were analyzed using the Statistical Package for Social Sciences, version 20.0 (SPSS Inc., Chicago, IL, USA). Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage. Independent samples *t* test of significance was used when comparing between two means. Chi-square ( $\chi^2$ ) test of significance was used in order to compare proportions between qualitative parameters. The confidence interval was set to 95%, and the margin of error accepted was set to 5%. *p* value < 0.05 was considered significant while *p* value < 0.001 was considered as highly significant.

### Results (Tables 1, 2, 3, 4, and 5)

### Discussion

The results of this study revealed no difference between PCV and VCV as regards postoperative oxygenation or the incidence of post-operative lung atelectasis. However, PCV showed better intraoperative oxygenation (PaO<sub>2</sub> and SaO<sub>2</sub>) compared to VCV.

Similar to the results of the current study, Movassagi and co-workers in 2017 carried a study on 70 obese patients undergoing laparoscopic

cholecystectomy. Their results showed that PCV resulted in higher intraoperative PaO<sub>2</sub> levels compared to VCV without significant differences in other post-operative complications including atelectasis (Movassagi et al. 2017).

Similarly, another study carried by Hans and colleagues in 2008 on forty morbidly obese patients undergoing laparoscopic gastric bypass surgery found no noteworthy differences between VCV and PCV regarding both postoperative complications (including atelectasis) and intraoperative oxygenation (Hans et al. 2008).

The results of the study carried by Gupta and colleagues in 2012 to assess the effects of PCV and VCV on intraoperative oxygenation in obese patients undergoing laparoscopic cholecystectomy matched the results of the current study. There were significantly higher intraoperative PO<sub>2</sub> levels and better oxygenation in patients who received PCV compared to those who received VCV and no noteworthy differences regarding postoperative complications including atelectasis (Gupta et al. 2012).

Moreover, in the study carried by Kothari and colleagues in 2018 on 75 patients undergoing laparoscopic cholecystectomy, significantly higher intraoperative PO<sub>2</sub> levels were found in patients who received PCV and PCV-VG compared to those who received VCV but no difference in post-operative oxygenation and complication including atelectasis.

**Table 4** PaCO<sub>2</sub> (mmHg)

PaCO <sub>2</sub>	Group (V), VCV (n = 26)	Group (P), PCV (n = 26)	t test	p value
<b>Preoperative</b>	33.64 ± 3.06	32.41 ± 4.32	1.593	0.124
<b>Intraoperative</b>	34.31 ± 3.12	32.55 ± 4.41	0.336	0.670
<b>30 min after extubation</b>	37.42 ± 3.73	36.46 ± 5.08	0.600	0.511
<b>12 h after extubation</b>	37.14 ± 4.14	35.63 ± 4.61	0.684	0.276
<b>24 h after extubation</b>	36.42 ± 3.49	35.58 ± 4.35	0.421	0.305

This table shows no statistically significant difference between groups according to PaCO<sub>2</sub>  
t independent sample t test, PCV pressure-controlled ventilation, VCV volume-controlled ventilation  
p value > 0.05 NS

**Table 5** Lung US finding. Data shown as number (percentage) of patients

Lung US finding	Group (V), VCV (n = 26)	Group (P), PCV (n = 26)	$\chi^2$	p value
<b>Immediate postoperative</b>				
Normal	8 (30.8%)	10 (38.5%)	0.143	0.368
Abnormal	18 (69.2%)	16 (61.5%)		
Absent A-lines	10 (38.5%)	8 (30.8%)		
Presence B-lines	14 (53.8%)	12 (46.2%)		
Lung pulse	14 (53.8%)	12 (46.2%)		
<b>After 12 h</b>				
Normal	10 (38.5%)	12 (46.2%)	0.513	0.282
Abnormal	16 (61.5%)	14 (53.8%)		
Absent A-lines	7 (26.9%)	5 (19.2%)		
Presence B-lines	12 (46.2%)	11 (42.3%)		
Lung pulse	12 (46.2%)	11 (42.3%)		
<b>After 24 h</b>				
Normal	12 (46.2%)	14 (53.8%)	0.328	0.325
Abnormal	14 (53.8%)	12 (46.2%)		
Absent A-lines	6 (23.1%)	5 (19.2%)		
Presence B-lines	9 (34.6%)	8 (30.8%)		
Lung pulse	9 (34.6%)	8 (30.8%)		

This table shows no statistically significant difference between groups according to lung US finding  $\chi^2$  chi-square test, PCV pressure-controlled ventilation, VCV volume-controlled ventilation  
p value > 0.05 NS

These results agree with the results of the current study (Kothari and Baskaran 2018).

Cadi and colleagues in 2008 carried a study on thirty-six morbidly obese patients who undergo laparoscopic gastric banding and found a significantly higher intraoperative  $PO_2$  levels in the PCV group compared to the VCV group. They stated that PCV generates higher instantaneous flow peaks and may allow better alveolar recruitment leading to improved oxygenation without any side-effects, but no difference in 2 h post-operative oxygenation and complications including atelectasis (Cadi et al. 2008).

Moreover, supporting the results of the current study, Aldenkortt and colleague in 2012 performed a meta-analysis of thirteen studies (505 obese surgical patients) reporting a variety of ventilation strategies: pressure- or volume-controlled ventilation (PCV, VCV), various tidal volumes, and different PEEP or recruitment manoeuvres (RM), and combinations and revealed that the ideal intraoperative ventilation strategy in obese patients remains obscure. There is no evidence of any difference between PCV and VCV as regards oxygenation and post-operative complications including lung atelectasis (Aldenkortt et al. 2012).

## Conclusion

Despite slight improvement in intraoperative oxygenation parameters ( $PO_2$ ,  $SO_2$ ) with PCV than VCV, there is no significant difference between VCV and PCV in prevention of postoperative pulmonary atelectasis; moreover, there is no difference in postoperative oxygenation parameters.

## Abbreviations

ABG: Arterial blood gas; BMI: Body mass index; OR: Operative room; PCV: Pressure-controlled ventilation; PEEP: Positive end-expiratory pressure; PPCS: Postoperative pulmonary complication; VCV: Volume-controlled ventilation; VT: Tidal volume

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## Authors' contributions

Ramy Mohammed Hassan designed the study, revised literature, followed up the patients, and critically reviewed the manuscript. Hoda Omar Mahmoud designed the study, analyze the data, and wrote and critically revised the manuscript. Wael Ahmed Abd El Aal, Mona Ahmed Mohamed, and Tarek Samir Shabana revised literature, followed up the patients, collected the data, performed the analysis, and wrote the manuscript. All authors approved the final version of the manuscript.

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## Availability of data and materials

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

**Ethics approval and consent to participate**

Approval of the research ethical committee of Faculty of Medicine, Ain-Shams University, was obtained (code number: FMASU M D 98/2018), and written informed consent was obtained from patients.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that they have no competing interests.

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