Rev Bras Anestesiol. 2019;69(6):546-552

REVISTA BRASILEIRA DE ANESTESIOLOGIA

Publicação Oficial da Sociedade Brasileira de Anestesiologia
www.sba.com.br

SCIENTIFIC ARTICLE

Comparison of volume-controlled and pressure-controlled ventilation on respiratory mechanics in laparoscopic bariatric surgery: randomized clinical trial

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Received 20 March 2019; accepted 13 August 2019
Available online 16 October 2019

KEYWORDS
Bariatric surgery;
Volume-controlled ventilation;
Pressure-controlled ventilation;
Respiratory mechanics

Abstract
Background: It is not clear which mechanical ventilation mode should be used in bariatric surgery, one of the treatment options for patients with obesity.
Objectives: To compare volume-controlled ventilation and pressure-controlled ventilation in terms of respiratory mechanics and arterial blood gas values in patients undergoing laparoscopic bariatric surgery.
Methods: Sixty-two patients with morbid obesity scheduled for gastric bypass were included in this study. Their ideal body weights were calculated during preoperative visits, and patients were divided into two groups, volume-controlled ventilation and pressure-controlled ventilation. The patients were ventilated in accordance with a previously determined algorithm. Mechanical ventilation parameters and arterial blood gas analysis were recorded 5 minutes after induction, 30 minutes after pneumoperitoneum, and at the end of surgery. Also, the dynamic compliance, inspired O_2 pressure/fractional O_2 ratio, and alveolar-arterial oxygen gradient pressure were calculated.
Results: Peak airway pressures were lower in patients ventilated in pressure-controlled ventilation mode at the end of surgery ($p = 0.011$). Otherwise, there was no difference between groups in terms of intraoperative respiratory parameters and arterial blood gas analyses.
Conclusions: Pressure-controlled ventilation mode is not superior to volume-controlled ventilation mode in patients with laparoscopic bariatric surgery.

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https://doi.org/10.1016/j.bjane.2019.08.004

PALAVRAS-CHAVE
Cirurgia bariátrica;
Ventilação controlada por volume;
Ventilação controlada por pressão;
Mecânica respiratória

Comparação das ventilações controlada por volume e controlada por pressão na mecânica respiratória em cirurgia bariátrica laparoscópica: estudo clínico randômico

Resumo
Justificativa: O modo de ventilação mecânica que deve ser usado em cirurgia bariátrica, uma das opções de tratamento para pacientes com obesidade, ainda não foi definido.
Objetivos: Comparar as ventilações controladas por volume e por pressão em termos de mecânica respiratória e dos valores da gasometria arterial em pacientes submetidos à cirurgia bariátrica laparoscópica.
Métodos: Foram inclu¡dos neste estudo 62 pacientes com obesidade mórbida programados para *bypass* gástrico. Seus pesos corporais ideais foram calculados durante as consultas pré-operatórias e os pacientes foram divididos em dois grupos: ventilação controlada por volume e ventilação controlada por pressão. Os pacientes foram ventilados de acordo com um algoritmo previamente determinado. Os parâmetros da ventilação mecânica e as análises da gasometria arterial foram registrados 5 minutos após a indução, 30 minutos após o pneumoperitônio e ao final da cirurgia. Além disso, a complacência dinâmica, a pressão e a fração de oxigênio inspirado e a pressão do gradiente alvéolo-arterial de oxigênio foram calculados.
Resultados: As pressões de pico das vias aéreas foram menores nos pacientes ventilados no modo de ventilação controlada por pressão ao final da cirurgia ($p = 0{,}011$). Exceto por esse aspecto, não houve diferença entre os grupos quanto aos parâmetros respiratórios intraoperatórios e às gasometrias arteriais.
Conclusões: O modo de ventilação controlada por pressão não é superior ao modo de ventilação controlada por volume em pacientes de cirurgia bariátrica laparoscópica.

Introduction

Morbid obesity has been a global health problem since the 1980s. In the USA, the proportion of the population over 20 years of age with morbid obesity is 35%.[1] Patients attempt to control their obesity with lifestyle changes, dietary regulation, and physical activity. However, bariatric surgery is indicated for patients with a life-threatening cardiopulmonary problem or serious diabetes mellitus combined with a Body Mass Index (BMI) over $35\,kg.m^{-2}$ and those with BMI > $40\,kg.m^{-2}$.[2]

Laparoscopic bariatric surgery was performed in 1994 after it was announced in 1991 that surgery was effective in helping patients to lose weight. Since then, the number of patients undergoing laparoscopic bariatric surgery has increased over the years.[3] Specific characteristics of laparoscopy have been added to the changes that occur due to anesthesia.

In patients with obesity, the supine position, muscle paralysis, and pneumoperitoneum result in a decrease in functional reserve capacity, an increase in closure capacity and susceptibility to atelectasis. Thus, the risk of postoperative complications and the duration of hospital stay increase, resulting in increased healthcare costs.[4] In addition, systemic vascular resistance increases as a result of the use of high intra-abdominal pressures during laparoscopy, and a decrease in mean arterial pressure occurs. Also, there is CO_2 absorption due to pneumoperitoneum, and if it is not effectively eliminated, acidosis and hypercapnia may occur.[3,5]

Although there are strategies for intraoperative management of patients with obesity, it is not clear which ventilation strategy is optimal.[1] Volume-controlled ventilation (VCV) is the most commonly used mode of ventilation for anesthetized patients. In this mode, a constant flow is applied to reach the targeted tidal volume (TV), and a specific minute volume is obtained. However, especially in patients with obesity, high airway pressures and hypoxia may occur due to increased intrapulmonary shunts. Pressure-Controlled Ventilation (PCV) is a mode used to improve gas exchange, especially in hypoxic intensive care patients.[6] During PCV, the pressure difference between the proximal airway and the alveoli is at a maximum, and most of the TV is given in the early period of the inspiratory phase. This has the effect of recruiting more alveoli. In addition, patients with the same TV and inspiratory time in PCV mode have higher mean airway pressures. This may help to improve arterial oxygen pressure.[6] In spite of this beneficial effect of PCV mode, studies comparing these two basic ventilation modes have yielded contradictory results.[7,8] Therefore, we aimed to investigate the potential of PCV mode to improve pulmonary gas exchange, respiratory mechanics, and arterial blood gas analyses relative to VCV mode in patients undergoing bariatric surgery.

Materials and methods

This study was carried out in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Training and Research Hospital, Antalya, Turkey

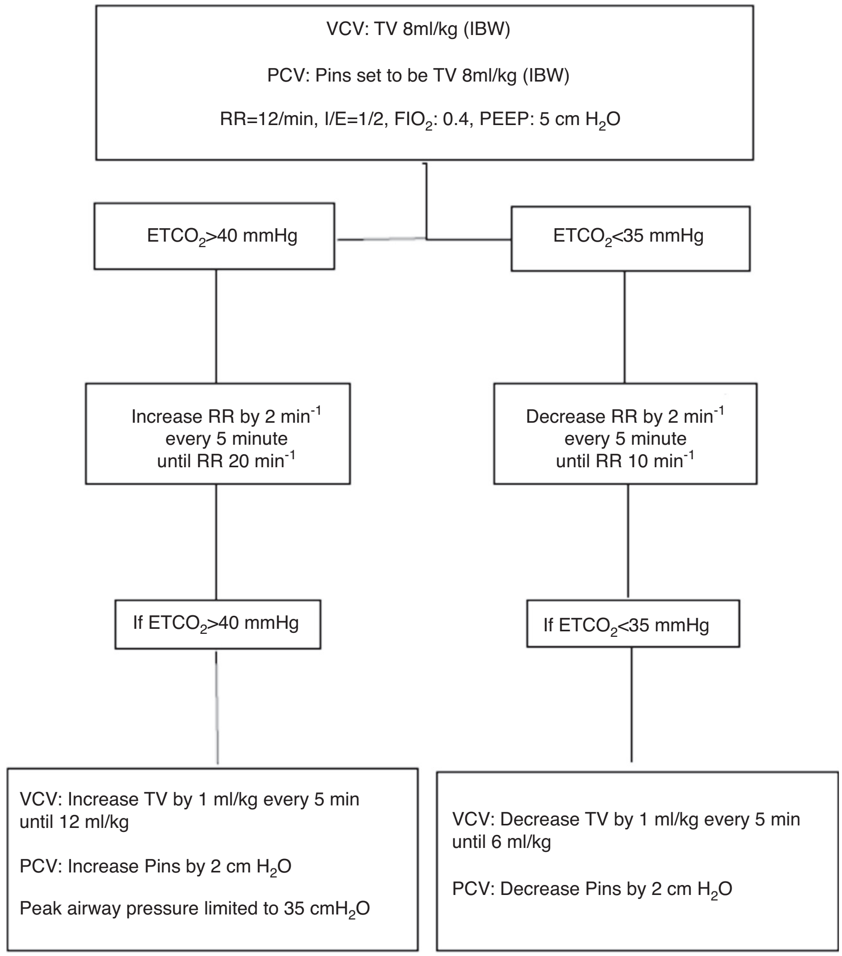

Figure 1 Algorithm for intra-operative ventilator settings. VCV, Volume-Controlled Ventilation Group; PCV, Pressure-Controlled Ventilation Group; IBW, Ideal Body Weight, TV, Tidal Volume; RR, Respiratory Rate; Pins, Inspiratory Pressure; FIO_2, Inspired Fraction of Oxygen; $ETCO_2$, End-Tidal CO_2; I/E, Inspiratory to Expiratory time ratio; PEEP, Positive End-Expiratory Pressure.

(Approval Number 2016-043). Written informed consent was obtained from all patients. Patients with a BMI greater than 40 kg.m^{-2} undergoing laparoscopic sleeve gastrectomy were enrolled in the study. The exclusion criteria included patients younger than 18 years, significant cardiopulmonary disease, history of uncontrolled hypertension, hepatic or renal dysfunction, and use of chronic alcohol or abuse of narcotic drugs. In addition, patients who needed mechanical ventilation in the postoperative period were excluded. The Ideal Body Weight (IBW) was calculated by using the formula (50 + 0.91 × length (cm) − 152.4) for men and (45.5 + 0.91 × length (cm) − 152.4) for women.[7] Patients willing to participate in the study were randomly separated into two groups, a VCV group and a PCV group, using a randomization scheme generated by software available online. (https://www.graphpad.com/quickcalcs/randMenu).

After administration of 1 mg midazolam to patients entering the operating room, standard monitoring including ECG, non-invasive blood pressure, pulse oximetry, and capnography was performed, and hemodynamic parameters were recorded. A cannula was inserted into the radial artery under local anesthesia. After 3 min of preoxygenation using a facial mask, 2 mg.kg^{-1} propofol, 1 μg.kg^{-1} of fentanyl and 0.6 mg.kg^{-1} of rocuronium were performed according to the IBW for tracheal intubation. Anesthesia was maintained with 2% sevoflurane and bolus doses of 1 μg.kg^{-1} fentanyl. Also bolus doses of 0.15 mg.kg^{-1} rocuronium were used to maintain muscle relaxation at <2 twitches (using a train-of-four sequence) of adductor pollicis muscle measured every 5 min. Patients were intubated in the supine position and then placed in a 30° head-up position. Laparoscopic sleeve gastrectomy operations were performed by the same surgical team, under 15 mmHg intra-abdominal pressure.

For mechanical ventilation, the Datex-Ohmeda Advance S5 (GE Healthcare, Helsinki, Finland) model device was used. During the operation, the algorithm in Fig. 1 was followed. Patients with an End-Tidal CO_2 ($ETCO_2$) value of greater than 45 mmHg or less than 30 mmHg and patients with a peak inspiratory pressure level above 35 cm H_2O and/or pulse oximetry value below 92% were excluded. Hemodynamic and mechanical ventilation parameters were recorded 5 min (T1) after induction, 30 min after pneumoperitoneum (T2), and at the end of surgery (T3), and arterial blood gas analysis was performed. In addition, dynamic compliance (TV/P peak − Positive end expiratory

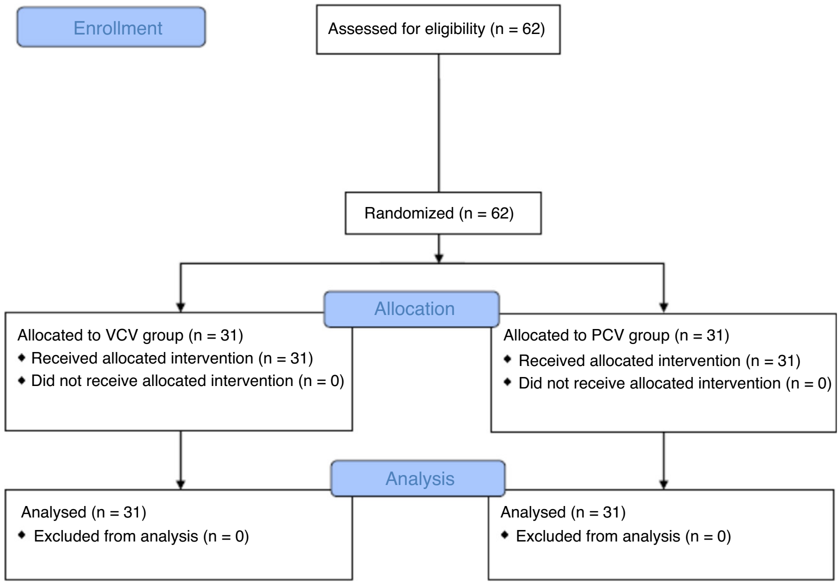

Figure 2 Consort flow diagram of the study. VCV, Volume-Controlled Ventilation; PCV, Pressure-Controlled Ventilation.

pressure), P/F ratio (inspired O_2 pressure/fractional O_2) and alveolar-arterial oxygen gradient pressure ($PA\text{-}aO_2$) were calculated.

Cadi et al.[7] reported an intraoperative PO_2 pressure of 168 ± 63 mmHg in the PCV group and 119 ± 44 mmHg in the VCV group. A calculated sample size of 26 patients per group was required to provide a statistical power of 0.80 and alpha of 0.05. Considering the possible dropout rate during the study, we decided to include 31 patients in each group. For statistical analysis, SPSS Windows version 17.0 (SPSS Inc., Chicago, IL) was used. All numerical data were tested for the normal distribution with the Shapiro-Wilk test. Continuous variables are presented as mean ± standard deviations. Categorical variables are presented as numbers of patients (n) and percentages (%). Differences between mean values for normally distributed variables were compared by using the Student's *t*-test. Non-normally distributed variables were compared by using the Mann-Whitney *U*-test. The Chi-squared test and Fisher's Exact test were used for categorical data where appropriate. Results were considered statistically significant at $p < 0.05$.

Results

A total of 62 patients (31 patients in each group) were included in the study (Fig. 2). No patients were excluded from the study. Operations were completed without complications. No patients underwent laparotomy. Patients' demographic and operative data were similar between the groups (Table 1).

In the PCV group, peak airway pressures were different at time T3 (Group VCV 22.7 ± 3.8 *vs.* group PCV 20.1 ± 3.7, $p = 0.011$). There were no other differences between groups in terms of other intraoperative hemodynamic data, respiratory parameters, and arterial blood gas analyses (Table 2–4).

Discussion

In this study, the superiority of PCV in terms of respiratory mechanics, arterial blood gas analysis and hemodynamic parameters could not be determined in patients undergoing bariatric surgery. Only the peak airway pressure in the PCV group was found to be lower at time T3. However, this result did not cause any difference in oxygenation.

In the practice of anesthesia, the most popular mode of mechanical ventilation is VCV. The use of other modes to control high airway pressures and improve oxygenation in patients with morbid obesity varies depending on the training and personal preferences of anesthesiologists.[9] In the literature, there is no gold standard method for ventilation strategies in patients undergoing bariatric surgery.[1,10] In two separate studies involving the same patient group as this study, while Cadi et al.[7] stated that PCV is beneficial, De Baerdemaeker et al. reported no difference between the two ventilation modes.[8] Cadi et al. reported a difference between groups with a single arterial blood gas analysis 45 min into the operation. In the study by De Baerdemaeker et al., all patients were started with VCV. Fifteen minutes after insufflation, the patients were divided into groups and in the next 15 min, arterial blood gas was studied. Then, the results were compared with the values obtained in room air. In contrast, in this study, patients were divided into groups from the beginning of the operation, and arterial blood gas analyses and respiratory mechanics data were recorded at three different times during the operation.

Intra-abdominal pressure is increased due to pneumoperitoneum that occurs during laparoscopic surgery. The diaphragm is pushed upward as a consequence of abdominal expansion. This leads to an increase in intrathoracic pressure and limitation of lung expansion. As a result, pulmonary dynamic compliance decreases, and peak airway pressure increases. Hence, ventilator-associated lung injury may occur during VCV.[9] Because of this, the most important reason for anesthesiologists to use PCV mode during bariatric

Table 1 The demographic and operative data of study groups.

	VCV (n = 31)	PCV (n = 31)	*p*-value
Age (years)	38.9 ± 10.7	42.19 ± 9.6	0.208
Sex F/M	27/4	25/6	0.490
IBW (kg)	57.45 ± 9.22	56.06 ± 7.46	0.516
BMI ($kg.m^{-2}$)	46.09 ± 4.36	46.61 ± 6.61	0.719
Presence of comorbidity n (%)	9 (29)	13 (42)	0.288
Surgery time (min)	78.26 ± 19.27	78.52 ± 19.96	0.959
Anesthesia time (min)	106.06 ± 19.6	104.61 ± 20.74	0.778
CO_2 insufflation time (min)	61.74 ± 17.87	59.77 ± 18.91	0.675

Data are given as mean ± standard deviation.
VCV, Volume-Controlled Ventilation; PCV, Pressure-Controlled Ventilation; IBW, Ideal Body Weight; BMI, Body Mass Index.

Table 2 Hemodynamic variables of study groups.

	VCV	PCV	*p*-value
Heart rate (beats/minutes)			
5 min after induction	80.7 ± 11	85 ± 12.6	0.160
30 min after pneumoperitoneum	81.5 ± 12.7	89.5 ± 12.9	0.271
The end of surgery	85.7 ± 13.8	81.8 ± 12.8	0.937
Systolic blood pressure (mmHg)			
5 min after induction	120.7 ± 15.3	121.7 ± 15.7	0.801
30 min after pneumoperitoneum	128.1 ± 19.2	123.6 ± 16.8	0.323
The end of surgery	126.7 ± 15.6	130.6 ± 16.2	0.340
Diastolic blood pressure (mmHg)			
5 min after induction	66.4 ± 12.1	68.5 ± 14	0.533
30 min after pneumoperitoneum	73.3 ± 11.8	74.7 ± 13.8	0.687
The end of surgery	69.1 ± 10.5	73.3 ± 11.2	0.134
Mean arterial pressure (mmHg)			
5 min after induction	87.5 ± 11.9	90.5 ± 12.3	0.326
30 min after pneumoperitoneum	95.1 ± 12.9	93.3 ± 14.1	0.601
The end of surgery	91.9 ± 10.6	95.7 ± 11.1	0.169

Data are given as mean ± standard deviation.
VCV, Volume-Controlled Ventilation; PCV, Pressure-Controlled Ventilation.

surgery is to control high airway pressures. Cadi et al.[7] used an average TV of 10.2 $mL.kg^{-1}$ according to IBW and found the mean peak airway pressure in the VCV Group to be 33 cm H_2O. Similarly, De Baerdemaeker et al.[8] ventilated patients with 10 $mL.kg^{-1}$ of TV according to IBW and experienced an average peak airway pressure of 29.4 cm H_2O in the VCV Group. In this study, 25 cm H_2O pressure was obtained in the VCV group when the patients were ventilated with 8 $mL.kg^{-1}$ according to IBW, and this did not cause any deterioration in oxygenation. Therefore, considering the IBW, ventilating patients with low TV may be beneficial for controlling peak airway pressures. According to Campbell et al.,[11] VCV and PCV are similar ventilator modes with different control variables. So, the use of low TVs based on IBW to control peak airway pressure can eliminate the differences between ventilation modes.

The P/F ratio and PA-aO_2 can also be used to evaluate pulmonary ventilation and gas exchange.[12] When FiO_2 is applied to patients at the fixed rate, P/F ratio is directly dependent on PO_2. In the literature, although some authors claim that pressure-controlled ventilation improves the P/F ratio,[7] others show no difference.[8,13,14] In this study, a decrease in the P/F ratio occurs with pneumoperitoneum. This phenomenon, which developed similarly in both groups, was eliminated with the termination of pneumoperitoneum. Cadi et al.[7] found that the PA-aO_2 was lower in the PCV group, while Aydın et al.[5] compared two ventilation modes in patients undergoing cholecystectomy and reported that the PA-aO_2 was small in the VCV Group. In this study, similar to De Baerdemaeker et al.,[8] there was no difference between the groups in PA-aO_2 with pneumoperitoneum.

CO_2 absorption due to pneumoperitoneum is normally eliminated by the lungs. If the amount of CO_2 absorbed is not controlled, it causes hypercapnia and acidosis. This leads to cardiac arrhythmia and pulmonary vasoconstriction. To avoid hypercapnia, $ETCO_2$ and $PaCO_2$ values should be closely monitored. During pneumoperitoneum, it is possible to prevent the increasing CO_2 load by changing the minute ventilation.[3] Gupta et al.[15] tried to keep the CO_2 level stable using higher MV. In contrast, De Baerdemaeker et al.[8] provided better CO_2 elimination when ventilating patients with VCV when MV values were similar. In this study, the dif-

Table 3 Respiratory parameters of study groups.

	VCV	PCV	*p*-value
Respiratory rate (per min)			
T1	13.1 ± 1.3	13.2 ± 1.5	0.608
T2	14.7 ± 1.9	14.6 ± 1.8	0.892
T3	14.6 ± 1.7	14 ± 1.9	0.223
Tidal volume (mL)			
T1	463.3 ± 59.3	448.9 ± 52.1	0.314
T2	464.2 ± 54.8	444.3 ± 46.8	0.129
T3	476.6 ± 58.4	450.5 ± 51.5	0.067
Minute volume ($L.min^{-1}$)			
T1	6.1 ± 1.1	5.7 ± 1.1	0.184
T2	6.7 ± 1.2	6.2 ± 1.1	0.108
T3	7.2 ± 1.5	6.8 ± 1.4	0.248
Peak airway pressure (cm H_2O)			
T1	23.3 ± 4.4	21.8 ± 4.7	0.208
T2	26.8 ± 3.4	25 ± 3.5	0.051
T3	22.7 ± 3.8	20.1 ± 3.7	0.011
SPO_2 (%)			
T1	97.9 ± 1.5	98.1 ± 1.7	0.701
T2	96.7 ± 2	96.6 ± 2.2	0.906
T3	97.8 ± 1.6	98.1 ± 1.3	0.463
End tidal CO_2 (mmHg)			
T1	36.2 ± 2.1	36.2 ± 2.6	0.753
T2	37.9 ± 1.7	37.5 ± 2.3	0.390
T3	37.8 ± 1.8	36.8 ± 2	0.065
Dynamic compliance ($mL. cm^{-1} H_2O$)			
T1	26.9 ± 8.2	28.2 ± 7.1	0.493
T2	21.7 ± 3.9	22.7 ± 4.3	0.329
T3	28.2 ± 7.3	31.2 ± 7.9	0.125
$PA\text{-}aO_2$ (mmHg)			
T1	121.5 ± 37	126.8 ± 24.7	0.515
T2	129.6 ± 31.4	129.9 ± 18.8	0.963
T3	117.2 ± 33.6	114.3 ± 25.5	0.708
P/F ratio			
T1	298.6 ± 94.2	285.5 ± 65.3	0.526
T2	270.8 ± 78.3	269.1 ± 46.6	0.918
T3	302.5 ± 85.9	307.5 ± 65.6	0.798

Data are given as mean ± standard deviation.
VCV, Volume-Controlled Ventilation; PCV, Pressure-Controlled Ventilation; Inspired O_2 pressure/Fractional O_2 (P/F) ratio.

ference was not detected in terms of CO_2 elimination. This may have been due to changes in the ventilation parameters according to $ETCO_2$ values and, consequently, to obtaining similar MV values.

The cardiopulmonary physiology and pathophysiology of the pneumoperitoneum are well known.[16] Balick-Weber et al., evaluated the hemodynamic effects of VCV and PCV ventilation by echocardiography in patients undergoing laparoscopic surgery and found no difference between groups.[14] Similarly, in this study, it was determined that ventilation with VCV or PCV had no effect on hemodynamics in patients undergoing bariatric surgery.

Table 4 Arterial blood gas analyses of study groups.

	VCV	PCV	*p*-value
PH			
T1	7.36 ± 0.03	7.38 ± 0.03	0.087
T2	7.34 ± 0.04	7.35 ± 0.04	0.473
T3	7.34 ± 0.03	7.35 ± 0.04	0.483
PO_2 (mmHg)			
T1	119.4 ± 37.7	114.2 ± 26.1	0.526
T2	108.3 ± 31.3	107.6 ± 18.6	0.918
T3	121 ± 34.3	123 ± 26.2	0.798
PCO_2 (mmHg)			
T1	38.8 ± 3.5	38.8 ± 4.6	0.988
T2	41.2 ± 3.2	41.5 ± 3.6	0.734
T3	41.1 ± 3.2	41.7 ± 4.5	0.497
$PCO_2\text{-}ETCO_2$ (mmHg)			
T1	2.4 ± 3.1	2.6 ± 4.5	0.835
T2	3.2 ± 3.1	4 ± 3	0.344
T3	3.2 ± 2.8	4.9 ± 3.6	0.058

Data are given as mean ± standard deviation.
VCV, Volume-Controlled Ventilation; PCV, Pressure-Controlled Ventilation; $ETCO_2$, End-Tidal CO_2.

Limitations

Although the sample size was sufficient to evaluate arterial blood gas values, it may not have been sufficient to detect rarer effects and complications of the procedures. Further studies with a larger sample size may be required to confirm the results of this study.

Conclusion

There is no difference between the VCVand PCV modes in patients undergoing laparoscopic bariatricsurgery in terms of respiratory mechanics, arterial blood gasanalyses, and hemodynamic parameters.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Shah U, Wong J, Wong DT, et al. Preoxygenation and intraoperative ventilation strategies in obese patients: a comprehensive review. Curr Opin Anaesthesiol. 2016;29:109–18.
2. Ogunnaike BO, Jones SB, Jones DB, et al. Anesthetic considerations for bariatric surgery. Anesth Analg. 2002;95:1793–805.
3. Nguyen NT, Wolfe BM. The physiologic effects of pneumoperitoneum in the morbidly obese. Ann Surg. 2005;241:219–26.
4. Almarakbi WA, Fawzi HM, Alhashemi JA. Effects of four intraoperative ventilatory strategies on respiratory compliance and gas exchange during laparoscopic gastric banding in obese patients. Braz J Anaesthesiol. 2009;102:862–8.
5. Aydin V, Kabukcu HK, Sahin N, et al. Comparison of pressure and volume-controlled ventilation in laparoscopic cholecystectomy operations. Clin Respir J. 2016;10:342–9.
6. Hans GA, Pregaldien AA, Kaba A, et al. Pressure-controlled ventilation does not improve gas exchange in morbidly

obese patients undergoing abdominal surgery. Obes Surg. 2008;18:71–6.
7. Cadi P, Guenoun T, Journois D, et al. Pressure-controlled ventilation improves oxygenation during laparoscopic obesity surgery compared with volume-controlled ventilation. Braz J Anaesthesiol. 2008;100:709–16.
8. De Baerdemaeker LE, Van der Herten C, Gillardin JM, et al. Comparison of volume-controlled and pressure-controlled ventilation during laparoscopic gastric banding in morbidly obese patients. Obes Surg. 2008;18:680–5.
9. Wang JP, Wang HB, Liu YJ, et al. Comparison of pressure- and volume-controlled ventilation in laparoscopic surgery: a meta-analysis of randomized controlled trial. Clin Invest Med. 2015;38:E119–41.
10. Aldenkortt M, Lysakowski C, Elia N, et al. Ventilation strategies in obese patients undergoing surgery: a quantitative systematic review and meta-analysis. Braz J Anaesthesiol. 2012;109:493–502.
11. Campbell RS, Davis BR. Pressure-controlled versus volume-controlled ventilation: does it matter? Respir Care. 2002;47: 416–24.
12. Zetterstrom H. Assessment of the efficiency of pulmonary oxygenation. The choice of oxygenation index. Acta Anaesthesiol Scand. 1988;32:579–84.
13. Tyagi A, Kumar R, Sethi AK, et al. A comparison of pressure-controlled and volume-controlled ventilation for laparoscopic cholecystectomy. Anaesthesia. 2011;66:503–8.
14. Balick-Weber CC, Nicolas P, Hedreville-Montout M, et al. Respiratory and haemodynamic effects of volume-controlled vs pressure-controlled ventilation during laparoscopy: a cross-over study with echocardiographic assessment. Braz J Anaesthesiol. 2007;99:429–35.
15. Gupta SD, Kundu SB, Ghose T, et al. A comparison between volume-controlled ventilation and pressure-controlled ventilation in providing better oxygenation in obese patients undergoing laparoscopic cholecystectomy. Indian J Anaesth. 2012;56:276–82.
16. Sharma KC, Brandstetter RD, Brensilver JM, et al. Cardiopulmonary physiology and pathophysiology as a consequence of laparoscopic surgery. Chest. 1996;110:810–5.