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ORIGINAL RESEARCH BARIATRIC ANESTHESIA

Comparative study between the effects of volume-controlled ventilation and pressure-controlled - volume guaranteed ventilation in patients with obesity during laparoscopic surgery

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ABSTRACT

Background & objective: Obesity has been termed as an epidemic in the developed countries, although it can also be seen in poor countries. With more and more obese surgical patients, anesthetic protocols have to be evolved. Ventilation of obese patients during surgery is seen to be a prime concern. The objective of this study was to evaluate the efficacy of Pressure Controlled Ventilation-Volume Guaranteed (PCV-VG) in comparison to volume-controlled ventilation (VCV) modes in obese patients undergoing laparoscopic assisted surgery in the Trendelenburg position, with a focus on their lung compliance and oxygenation index (OI).

Methodology: This randomized controlled clinical trial involved 64 obese patients of both sexes, all with a Body Mass Index (BMI) of ≥ 30 kg/m², and classified as ASA class I or II. The participants were randomly assigned to two equal groups: the study group (Group P) using PCV-VG and the control group (Group V) using VCV.

Results: The arterial oxygen partial pressure (PaO_2) and lung compliance were significantly higher in Group P compared to Group V ($P < 0.05$). Conversely, the peak pressure (P peak) and plateau pressure (P_{plat}) along with the mean pressure (P mean) as well as the oxygenation index were significantly lower in Group P compared to Group V ($P < 0.05$).

Conclusions: PCV-VG significantly improves lung compliance and oxygenation while maintaining lower peak and plateau pressures, with comparable hemodynamic stability and $PaCO_2$ levels.

Abbreviations: ASA: American Society of Anesthesiologists, BMI: Body Mass Index, $EtCO_2$: end-tidal carbon dioxide, OI: oxygenation index, PCV-VG: Pressure Controlled Ventilation-Volume Guaranteed, PIP: Peak Inspiratory Pressure, PaO_2: arterial oxygen partial pressure, P peak: peak pressure, P_{plat}: plateau pressure, PRVC: pressure-regulated volume-controlled, VCV: volume-controlled ventilation,

Keywords: Airway Pressure; Obesity; Oxygenation index; Pressure-Controlled Ventilation-Volume-Guaranteed; Trendelenburg position; Ventilation; Volume-Controlled Ventilation

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1. INTRODUCTION

Obesity is characterized by elevated resistance to airflow, difficulty in breathing and reduced respiratory system compliance, with a Body Mass Index (BMI) exceeding 30 kg/m^2.[1]

The combination of Carbon dioxide pneumoperitoneum with or without precipitous Trendelenburg positioning is typically necessary for assisted laparoscopic surgery to achieve an optimal surgical perspective. However, this approach can result in heightened airway pressure and adverse impacts on gas exchange.[2]

Elevated atelectasis and cranial displacement of the diaphragm are consequences of carbon dioxide pneumoperitoneum in conjunction with steep Trendelenburg positioning. This condition leads to a reduction in total lung volume, decreased lung compliance, and decreased functional residual capacity. Therefore, the primary objectives of anesthetic management during laparoscopic-assisted surgery are to mitigate elevated airway pressures, enhance oxygenation, and facilitate the removal of carbon dioxide.[3]

In the context of laparoscopic assisted surgery, elevation of intra-abdominal pressure due to CO_2 pneumoperitoneum can lead to various complications, including deterioration in oxygenation, increase in airway pressure, reduction in lung volume and compliance, and elevated risk of atelectasis. Consequently, these factors can contribute to the development of hypercapnia, acidosis, and impaired oxygenation.[4]

Volume-Controlled Ventilation (VCV) is the optimal method during general anesthesia. This mode of ventilation guarantees sufficient minute ventilation and delivers a target tidal volume (V_T) through a constant flow. However, this approach can result in increased airway pressure during laparoscopic assisted surgery.[5]

To obtain the optimal V_T, the ventilator regulates the Peak Inspiratory Pressure (PIP) in Pressure Controlled Ventilation-Volume Guaranteed (PCV-VG) mode. The ventilator parameters are consistently modified without altering the airway pressure to achieve the desired volume. Therefore, PCV-VG offers the benefits of both VCV and Pressure Controlled Ventilation (PCV) in that it minimizes the occurrence of barotrauma, while maintaining the target minute ventilation.[6]

PCV-VG is a type of controlled ventilation mode that integrates the characteristics of both PCV and VCV. This mode functions as a pressure-regulated volume-controlled (PRVC) system employing autoflow ventilation. The design allows for a reduction in inspiratory pressure; which, in turn, minimizes the risk of barotrauma.[3]

PCV-VG is a secure ventilation method without related problems or any inferiority in maximal airway pressure, plateau pressure, and dynamic compliance, with the potential to offer advantages in terms of enhanced airway dynamics compared with VCV.[7]

Objectives

This study aimed to evaluate the efficacy of PCV-VG and VCV modes in obese patients, who underwent laparoscopic aided surgery in the Trendelenburg position with respect to lung compliance and oxygenation index (OI).

2. METHODOLOGY

This investigation was registered as an investigational study with registration number NCT06117748. It was a randomized controlled trial, which included 64 obese patients, 21-60 years old, of both sexes, with BMI ≥ 30 kg/m^2, ASA class I/ II and undergoing laparoscopic assisted surgery. The research was conducted over a span of one year following approval from our institutional ethics committee under reference number FMASU MD 280/2022. Written informed consent was obtained from all patients.

The criteria for exclusion were as follows: ASA III or IV, intraoperative hemodynamic instability, obese patients on home oxygen therapy, pneumoperitoneum with carbon dioxide with intra-abdominal pressure exceeding 14 mmHg, anti-Trendelenburg position, asthmatic patients, patients with [advanced renal, liver disease, pulmonary hypertension and advanced malignancy], and pregnancy.

The patients were divided into two equal groups: Group P (PCV-VG), representing the study group; and Group V (VCV), representing the control group. The use of a random number table and a closed envelope technique were used to randomly assign patients to one of the two groups.

Prior to surgery, a detailed medical history was obtained from each patient, followed by a comprehensive clinical examination. All pertinent investigations were reviewed, including complete blood count (CBC), coagulation profile, liver enzyme levels, kidney function tests, electrocardiogram (ECG), echocardiography (ECHO), pulmonary function tests, and arterial blood gas analysis (ABG). Subsequently, each patient was administered premedication comprising ondansetron 8 mg, a prokinetic agent, delivered intravenously, in addition to famotidine 20 mg IV, an H_2 blocker, after the establishment of a 20G peripheral venous access. After sterilizing the skin with an alcohol swab, a local anesthetic was applied. Monitoring of ECG, noninvasive blood pressure monitoring, and pulse oximetry, was started. Following a preoxygenation period of 3-5 min, anesthesia was administered via fentanyl 1-2 µg/kg and propofol 2 mg/kg IV over 15 seconds, and atracurium 0.5 mg/kg. Tracheal intubation was performed using a direct laryngoscope. After confirming the ETT position through capnography, an arterial line was successfully inserted into the left radial artery using a 3-Fr Vygon catheter, following the performance of a modified Allen test.

The respiratory parameters were set as follows: actual V_T 8 mL/kg, respiratory rate 12 breaths/min, PEEP 5 mmHg, oxygen flow 4 L/min, FiO_2 0.6, and I:E ratio of 1:2. Anesthesia was maintained using 1.5-2.5 vol% end-tidal sevoflurane to regulate hemodynamic responses during the surgical procedure, keeping within a 20% range of the preoperative values.

The respiratory parameters were consistently monitored and maintained at a stable level when the $EtCO_2$ remained below 45 mmHg. In cases where $EtCO_2$ exceeded 45 mmHg, adjustments were made to either the respiratory rate or tidal volume to ensure that $EtCO_2$ levels remained below this threshold. The patient was positioned supine, and pneumoperitoneum was executed with CO_2 at an intraabdominal pressure of 14 mmHg. The operative table was then inclined to achieve a 30° Trendelenburg position. Lactated Ringer's solution was administered continuously at a rate of 6-8 mL/kg/hr throughout the study period.

Data collection:

Hemodynamic parameters: mean arterial blood pressure (MAP) and heart rate were monitored for 10 min prior to anesthesia administration (T0), immediately following the onset of pneumoperitoneum, each 10 min within the initial hour, and at the conclusion of surgery. The ABGs were examined using a blood gas analyzer at T0 (the baseline ABG done in preoperative investigations) and approximately every 10 min during the initial one hour. Lung mechanics including peak airway pressure (P peak), plateau pressure (P_{plat}), mean airway pressure (P mean), and compliance of the respiratory system were recorded following ETT insertion (T0) and every 10 min in the first hour.

Primary outcome: OI (computed as mean airway pressure × FiO_2 × 100/ PaO_2).

Secondary outcomes: MAP, HR, SpO_2, $PaCO_2$, and lung compliance

Sample Size Calculation:

At least 32 cases per category comprise the sample – a total of 64 cases – achieves a power of 80% to detect an effect size of 0.3 within as well as between the groups using repeated measure ANOVA with in-between factor with level of significance of 0.05. A correlation of at most 0.5 was assumed between the repeated measures and 20% excess cases were added to compensate for the potential of drop-outs.[8]

Statistical analysis:

All statistical analyses were performed using SPSS v26 (IBM Inc., Chicago, IL, USA). The mean and standard deviation (SD) of quantitative variables, are presented. and compared between the two groups using an unpaired Student's t-test. Frequency and percentage (%) were employed to represent qualitative variables. and analyzed using the Chi-square test. $P < 0.05$ was considered significant.

3. RESULTS

In this investigation, eligibility assessments were conducted for 81 patients, 12 patients did not satisfy the criteria, and 5 patients declined to participate in the investigation. The others were randomly assigned into

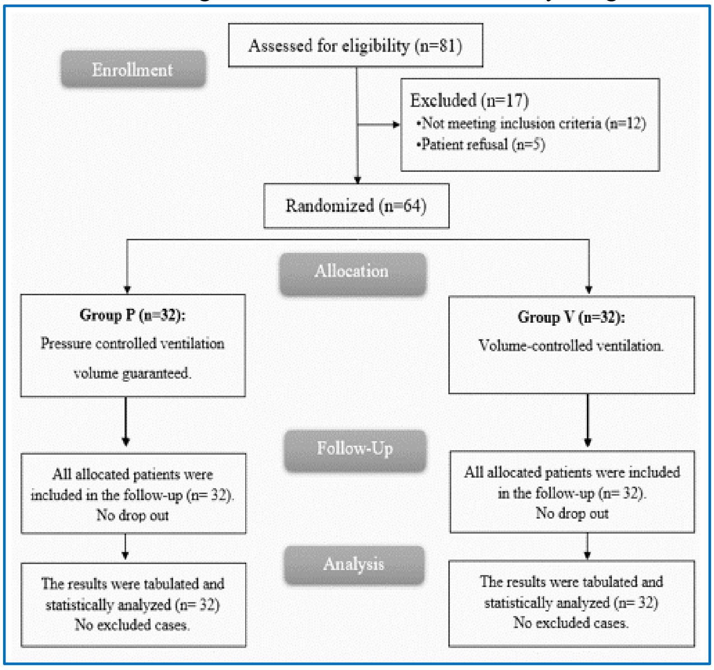

Figure 1: CONSORT flowchart of the study population

Table 1: Demographic data and surgery duration in the studied groups

Parameter		Group P (n = 32)	Group V (n = 32)	P value
Age (years)		42.38 ± 10.64	45.5 ± 11.29	0.259
Gender	**Male**	15 (46.88)	11 (34.38)	0.309
	Female	17 (53.13)	21 (65.63)	
Weight (kg)		98.97 ± 14.63	104.09 ± 10.6	0.114
Height (cm)		164.34 ± 6.3	166.97 ± 5.23	0.074
BMI (kg/m^2)		36.65 ± 5.1	37.47 ± 4.7	0.508
ASA physical status	**I**	20 (62.5)	22 (68.75)	0.599
	II	12 (37.5)	10 (31.25)	
Duration of surgery (min)		55.31 ± 16.99	59.69 ± 16.65	0.302

Data presented as mean ± SD or frequency (%). BMI: Body mass index, ASA: The American Society of Anesthesiologists.

two equal groups (32 patients in each). The statistical analysis and follow-up of all allocated patients were conducted (Figure 1).

There were no significant differences between the two groups with respect to demographic data and surgical duration (Table 1).

HR, MAP, PaO_2 at 10 min and at the end of surgery, $PaCO_2$, and P peak after intubation and at 10 min, were insignificantly different between both groups. PaO_2 at 20, 30, 40, 50 and 60 min was significantly higher in Group P than in group V ($P < 0.05$). P peak at 20, 30, 40, 50 and 60 min and at the end of surgery was significantly lower in Group P than in Group V ($P < 0.05$) (Table 2).

P_{plat} at T0 and 10 min, P mean after intubation, lung compliance after intubation, and oxygenation index after intubation, at 10 min and at the end of surgery, were not significantly different between both groups.

Lung compliance at 10, 20, 30, 40, 50 and 60 min and at the end of surgery were significantly higher in Group P than in Group V ($P < 0.05$).

P_{plat}, P mean and oxygenation index at 10, 20, 30, 40, 50 and 60 min and at the end of surgery were significantly lower in Group P than in Group V ($P < 0.05$) (Table 3).

HR and MAP immediately after pneumoperitoneum were not significantly different between the two groups (Table 4).

4. DISCUSSION

CO2 pneumoperitoneum is frequently used in conjunction with the Trendelenburg position during laparoscopic interventions to ensure appropriate surgical viewing and space.[9]

These methods significantly affect cardiovascular and pulmonary systems. These conditions lead to increased mean arterial pressure, higher P peak, reduced pulmonary compliance, and increased risk of barotrauma or atelectasis.[14]

The objective minute ventilation can be ensured through the application of VCV in anesthesia; Nevertheless, a constant flow rate may lead to a greater PIP, which can exacerbate the risk of barotrauma and cause an imbalanced distribution of pulmonary gases.[6]

In our study, the MAP was not significantly different at T0, 10 min, 20 min, 30 min, 40 min, 50 min, 60 min, and the end of surgery between both groups.

Consistent with our results, Civraz et al.[10] exhibited that there was no significant difference in MAP between VCV and PCV-VG in patients undergoing laparoscopic cholecystectomy.

In the present study, PaO_2 was insignificantly different at 10 min and at the end of surgery between both groups and was significantly higher at 20, 30, 40, 50, and 60 min in Group P than in group V ($P < 0.05$).

Nevertheless, Civraz et al.[10] showed no significant difference between VCV and PCV-VG in cases undergoing laparoscopic cholecystectomy regarding PaO_2 at all measurement intervals. This finding may be attributable to the positional disparity and the timeframe of the arterial blood gas analysis in the two investigations.

Toker et al.[5] found a significantly greater PaO_2 in the PCV-VG mode employed in the Trendelenburg position in obese patients.

In the current investigation, the P peak was insignificantly different after intubation and 10 min between both groups and was significantly lower at 20, 30, 40, 50, and 60 min and the end of surgery in Group P than in group V ($P < 0.05$).

Ahmed et al.[11] also showed that there was a significantly higher P peak in the VCV group in contrast to PCV-VG at T1 (prior to pneumoperitoneum), T2 (fifteen minutes following

Table 2: Comparative hemodynamic and P peak data of the studied groups

Parameter	Time	Group P (n = 32)	Group V (n = 32)	P value
HR (bpm)	**Before induction (T0)**	77.09 ± 9.72	79.38 ± 8.54	0.323
	10 min	75.03 ± 9.65	77.91 ± 8.61	0.213
	20 min	73.69 ± 9.82	76.81 ± 8.62	0.181
	30 min	71.81 ± 9.78	75.34 ± 8.63	0.131
	40 min	73.59 ± 10.03	72.66 ± 8.83	0.693
	50 min	71.47 ± 9.76	75.44 ± 8.56	0.089
	60 min	70.66 ± 9.48	74.31 ± 8.48	0.109
	End of surgery	72.56 ± 9.64	75.78 ± 8.85	0.169
MAP (mmHg)	**Before induction (T0)**	93.5 ± 12.33	93.78 ± 10.96	0.923
	10 min	89.34 ± 12.49	92.13 ± 10.92	0.347
	20 min	87.97 ± 12.28	91.41 ± 10.81	0.239
	30 min	89.44 ± 12.39	87.66 ± 11.09	0.547
	40 min	86.13 ± 12.44	89.41 ± 11.07	0.269
	50 min	86.44 ± 12.91	89.78 ± 10.91	0.267
	60 min	84.94 ± 12.46	88.66 ± 10.81	0.207
	End of surgery	87.19 ± 12.12	90.25 ± 11.33	0.300
PaO_2 (mmHg)	**10 min**	181.75 ± 18.44	177.13 ± 18.92	0.326
	20 min	181.25 ± 18.66	166 ± 19.28	**0.002***
	30 min	176.59 ± 18.97	163.75 ± 19.87	**0.010***
	40 min	173.28 ± 18.82	160.47 ± 20.2	**0.011***
	50 min	177.88 ± 18.41	168.09 ± 18.89	**0.040***
	60 min	181.13 ± 18.56	170.81 ± 19.16	**0.033***
	End of surgery	182.06 ± 18.64	174.28 ± 19.62	0.109
$PaCO_2$ (mmHg)	**10 min**	35.84 ± 4.33	36.69 ± 4.43	0.444
	20 min	35.88 ± 4.27	36.59 ± 4.32	0.506
	30 min	35.03 ± 4.45	36.03 ± 4.4	0.369
	40 min	36.78 ± 4.3	37.91 ± 4.28	0.298
	50 min	37.28 ± 4.56	38 ± 4.43	0.525
	60 min	38.31 ± 4.23	39.97 ± 4.75	0.146
	End of surgery	39.19 ± 4.4	40.31 ± 4.34	0.307
P peak (cmH_2O)	**After intubation (T0)**	15.38 ± 3.52	16.91 ± 4.31	0.124
	10 min	17.72 ± 3.4	18.84 ± 4.3	0.250
	20 min	21.63 ± 4.01	24.56 ± 4.13	**0.005***
	30 min	23.84 ± 4.21	27.06 ± 4.6	**0.005***
	40 min	24.91 ± 3.4	28.13 ± 4.34	**0.002***
	50 min	24.28 ± 3.67	27.56 ± 4.34	**0.002***
	60 min	24.75 ± 3.95	29.06 ± 4.92	**< 0.001***
	End of surgery	23.59 ± 3.26	26.81 ± 4.5	**0.002***

Data are presented as mean ± SD, PaO_2: partial oxygen pressure. MAP: Mean arterial blood pressure. HR: heart rate
**Significant as $P \leq 0.05$.*

pneumoperitoneum), and T3 (Five minutes following desufflation).

In our study, P_{plat} was insignificantly different at T0 and 10 min between the two groups and was significantly lower at 20, 30, 40, 50, 60 min, and the end of surgery in Group P than in group V ($P < 0.001$).

In this context, Civraz et al.[10] demonstrated that the P_{plat} results were significantly higher in the VCV group

Table 3: Comparative respiratory indices of the study groups

Parameter	Time	Group P (n = 32)	Group V (n = 32)	P value
P plateau (cmH_2O)	**After intubation (T0)**	15.25 ± 3.39	13.91 ± 4.31	0.170
	10 min	17.53 ± 3.41	15.84 ± 4.3	0.087
	20 min	21.38 ± 4	23.56 ± 4.13	**0.035***
	30 min	23.72 ± 3.98	26.06 ± 4.6	**0.033***
	40 min	24.88 ± 3.46	27.16 ± 5.02	**0.038***
	50 min	24.13 ± 3.37	26.91 ± 4.79	**0.009***
	60 min	24.56 ± 3.96	28.06 ± 4.63	**0.002***
	End of surgery	23.41 ± 3.39	25.94 ± 4.89	**0.019***
Mean P value (cmH_2O)	**After intubation (T0)**	8.19 ± 1.38	8.91 ± 2.1	0.111
	10 min	8.56 ± 1.54	10.47 ± 2.24	**< 0.001***
	20 min	9.81 ± 1.57	11.53 ± 2.26	**0.001***
	30 min	9.69 ± 1.49	11.22 ± 2.2	**0.002***
	40 min	9.78 ± 1.5	11.28 ± 2.26	**0.003***
	50 min	9.63 ± 1.45	11.38 ± 2.12	**< 0.001***
	60minP	9.97 ± 1.67	11.78 ± 2.14	**< 0.001***
	End of surgery	10.69 ± 1.35	12.53 ± 2.08	**< 0.001***
Lung Compliance (mL/cmH_2O)	**After intubation (T0)**	42.72 ± 6.69	40.5 ± 8.2	0.240
	10 min	37.75 ± 7.22	30.75 ± 8.61	**0.001***
	20 min	32.22 ± 7.16	27.53 ± 8.89	**0.023***
	30 min	27.69 ± 6.78	23.69 ± 8.71	**0.045***
	40 min	25.84 ± 6.65	21.94 ± 8.31	**0.042***
	50 min	24.41 ± 6.63	17.16 ± 8.25	**< 0.001***
	60 min	22.06 ± 7.09	17.38 ± 8.51	**0.020***
	End of surgery	21.38 ± 7.38	17 ± 8.46	**0.031***
Oxygenation index	**After intubation (T0)**	18.16 ± 1.27	18.38 ± 1.52	0.535
	10 min	13.31 ± 3.27	14.69 ± 2.9	0.080
	20 min	13.66 ± 2.77	15.38 ± 2.54	**0.012***
	30 min	12.94 ± 2.56	14.94 ± 2.65	**0.003***
	40 min	13 ± 2.49	14.94 ± 2.35	**0.002***
	50 min	13.13 ± 2.18	14.59 ± 2.84	**0.024***
	60 min	13.81 ± 2.64	15.38 ± 2.46	**0.017***
	End of surgery	13.81 ± 2.68	15.06 ± 2.71	0.068

*Data are presented as mean ± SD, *Significant as P ≤ 0.05.*

Table 4: Comparative hemodynamic data immediately after pneumoperitoneum

Parameter	Group P (n = 32)	Group V (n = 32)	P value
Heart rate immediately after pneumoperitoneum (beat/min)	74.63 ± 9.69	77.72 ± 9.09	0.193
MAP immediately after pneumoperitoneum (mmHg)	89.19 ± 12.24	92.03 ± 11.61	0.344

Data are presented as mean ± SD. MAP: Mean arterial blood pressure.

than in the PCV-VG group in patients undergoing

laparoscopic cholecystectomy.

In our study, Lung compliance was insignificantly different after intubation between the two groups and was significantly higher at 10 min, 20 min, 30 min, 40 min, 50 min, 60 min, and the end of surgery in Group P than in group V ($P < 0.05$).

Consistent with our findings, Civraz et al.[10] found that compliance measures were significantly lower. in the VCV group than in the PCV-VG group ($p < 0.05$). Moreover, it was noticed the pre-pneumoperitoneum measurement was 15% lower in the volts group than in the P group.

Recently, a meta-analysis by Schick et al.[7] comparing VCV and PCV-VG showed higher dynamic compliance of the lung in PCV-VG mode.

In our study, the Oxygenation index was insignificantly different after intubation, 10 min, and the end of surgery between both groups and was significantly lower at 20, 30, 40, 50, and 60 min in Group P than in group V ($P < 0.05$).

In line with our results, Toker et al.[5] compared the VCV and PCV-VG modes in laparoscopic gynecologic surgery. In this study, Toker et al.[5] observed an increase in oxygenation in addition to the PCV-VG ventilation parameters.

Some studies[12,13] have noted a significantly high

oxygenation (high PaO_2) as well as improved ventilation with PCV mode; in contrast, other researchers did not observe any significant difference in relation to oxygenation and ventilation.

5. LIMITATIONS

The limitations of this investigation were the relatively small sample size and the single-center investigation.

6. CONCLUSION

PCV-VG is a superior strategy for ventilation compared with VCV in obese patients who undergo laparoscopic surgery in the Trendelenburg position. PCV-VG significantly enhances lung compliance and oxygenation while maintaining lower peak and plateau pressures with comparable hemodynamic stability and $PaCO_2$.

7. Data availability

The numerical data generated during this research is available with the authors.

8. Conflict of interest

All authors declare that there was no conflict of interest.

9. Funding

The study utilized the hospital resources only, and no external or industry funding was involved.

10. Authors' contribution

AM: conduction of the study work

MES: manuscript editing

ST, AY: literature search

AEA: statistical analysis and review

AY: literature search

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