RESEARCH ARTICLE

Clinical application of a ventilation strategy based on the P-V curve in obese patients undergoing gynaecological laparoscopic surgery

Zhixia Zhou[1], Guofang Fei[2], Qi Zhang[3], Yi Ru[4]

Abstract

Objective: To explore the clinical value of pressure-controlled ventilation-volume guaranteed (PCV-VG) strategy based on the pressure-volume curve method in obese patients undergoing gynaecological laparoscopic surgery.

Method: The retrospective study was conducted in December 2021 after approval from the ethics review committee of Huzhou Maternal and Child Health Hospital, China, and comprised clinical records of obese patients who underwent elective gynaecological laparoscopic surgery between January 2020 and October 2021. The patients were divided into study group A, who underwent surgery with PCV-VG, and control group B, who underwent surgery without the PCV-VG. Ventilation parameters in group A were individually set according to the pre-pneumoperitoneum pressure-volume curves. Respiratory parameters, peak airway pressure, end-tidal carbon dioxide partial pressure, mean arterial pressure and patients' postoperative comfort scores were compared between the groups after tracheal intubation, pneumoperitoneum, and postural positioning. Data was analysed using SPSS 22.

Results: Of the 200 patients, 40(20%) were cases of laparoscopy myomectomy, 152(76%) cases of ovarian cystectomy, and 8(4%) cases of hysterectomy. There were 100(50%) females in group A with a mean age of 43.15±4.24 years, and 100(50%) were in group B with a mean age of 42.69±4.01 years (p=0.12). The peak airway pressure, mean arterial pressure, pneumoperitoneum pressure, and head-down tilt of the patients in group A were significantly lower post-pneumoperitoneum and post-positioning (p<0.05). At the same time, the respiratory rate was considerably higher (p<0.05) than that in group B. The end-tidal carbon dioxide partial pressure value at all time points was not significantly different between the groups (p>0.05). Postoperative comfort scores of patients in group A were significantly higher than those of group B (p<0.05).

Conclusion: PCV-VG, based on the pressure-volume curve, significantly reduced intraoperative peak airway pressure, was associated with smoother haemodynamic, and regulated intraoperative pneumoperitoneal pressure and position in obese patients undergoing gynaecological laparoscopic surgery. The ventilation method also significantly improved the patients' postoperative comfort.

Keywords: P-V curve, PCV-VG, Obese, Posture, Pneumoperitoneum pressure, Laparoscopy. (JPMA 75: 743; 2025)

DOI: https://doi.org/10.47391/JPMA.20946

Introduction

Laparoscopic surgery in obese gynaecological patients has the advantages of small surgical trauma and low risk of postoperative lower limb venous thrombosis and pulmonary atelectasis.[1] However, the pneumoperitoneum pressure and posture (head-down tilted) during laparoscopy can lead to upward displacement of the diaphragm and dorsal lung atelectasis, seriously affecting the recovery of the patient's respiratory function in the postoperative period. Furthermore, higher pneumoperitoneum pressure and greater angle of the head-down tilt position correlate with a higher incidence rate of adverse effects and a more profound impact on the recovery of the patient's respiratory function.[2,3] Obese patients have insufficient lung reserve capacity[4,5] and their respiratory function is more likely to be impaired, further aggravating the adverse effects of pneumoperitoneum pressure and posture.[6-8] Therefore, intraoperative regulation of pneumoperitoneal pressure and posture in obese patients has a more significant impact on prognosis, which puts higher demands on intraoperative care. Protective ventilation strategies can reduce postoperative pulmonary complications and promote rapid postoperative recovery.[9] Some studies have proved that the pressure-controlled ventilation-volume guaranteed (PCV-VG) strategy is an effective individualized protective ventilation method that improves dynamic lung compliance (Cdyn).[10]

The current study was planned to investigate the feasibility and protective effect of PCV-VG strategy based on pressure-volume (P-V) curves and its ability to regulate the

[1,4]Department of Operating Room, Huzhou Maternity & Child Health Care Hospital, Huzhou, China; [2,3]Department of Anaesthesia, Huzhou Maternity & Child Health Care Hospital, Huzhou, China.

Correspondence: Yi Ru. e-mail: 13735195029@163.com

ORCID ID: 0009-0009-4671-0976

Submission complete: 26-06-2024 **1st Revision received:** 02-08-2024

Acceptance: 19-02-2025 **Last Revision received:** 18-02-2025

pneumoperitoneum pressure and posture of obese patients during gynaecological laparoscopic surgery.

Materials and Methods

The retrospective study was conducted in December 2021 after approval from the ethics review committee of Huzhou Maternal and Child Health Hospital, China, and comprised clinical records of obese patients who underwent elective gynaecological laparoscopic surgery between January 2020 and October 2021. Data was collected from the institutional anaesthesia information management system (AIMS).

The initial screening was done by an anaesthesiologist using AIMS. For cases that met the inclusion criteria, the patient's age, BMI, ASA classification, peak airway pressure, and mean arterial pressure were recorded. For cases with missing information in the AIMS record, the anaesthesia record sheet (paper version) was reviewed to complete the relevant information. The enrolled patients were grouped according to whether they were switched to pressure-controlled volume-compensated ventilation (PCV-VG) mode after pneumoperitoneum. The study group A underwent surgery with PCV-VG, and the control group B underwent surgery without PCV-VG. The sample size was calculated with the PASS software[11] using the peak airway pressure (Ppeak) after the intraoperative postural position of the patients in both groups as the main index. The mean value for groups A and B was 30.55±1.01 and 31.03±1.28, respectively, at a test level of 0.05 and a test efficacy of 0.80. The sample size was inflated to include 100 medical records in each group for statistical convenience.

Those included were patients aged 25-55, with a body mass index (BMI) of 28-35kg/m^2 and American Society of Anaesthesiologists (ASA) classification I-II.[12]

Those excluded were patients with respiratory diseases, such as asthma, chronic obstructive pulmonary emphysema, bronchodilatation, respiratory infections, hypertension, coronary atherosclerotic heart disease, diabetes mellitus, and abnormalities of liver and kidney functions. Smokers were also excluded.

All patients were strictly made to fast for 8 hours and to abstain from drinking for 2 hours before the surgery, and no preoperative medication was used. After the patients were admitted to the operating theatre (OT), oxygen was administered by mask, intravenous (IV) access was opened, and electrocardiogram (ECG), heart rate (HR), invasive arterial blood pressure, oxygen saturation (SpO_2) and central venous pressure, as per the patient's condition and surgical needs, were monitored. Anaesthesia was induced using sequential intravenous midazolam, propofol, cis-atracurium and sufentanil. Anaesthesia maintenance was done through IV pumping of remifentanil, propofol, intermittent static injection of cis-atracurium, sevoflurane inhalation, and maintenance of bispectral index (BIS) value 40-60. After tracheal intubation, the patients were mechanically ventilated with fraction of inspired oxygen (FiO_2) 70% and an inspiratory/expiratory ratio of 1:2.

Patients in the control group underwent volume-controlled ventilation after tracheal intubation, with a tidal volume of 7ml/kg, respiratory rate of 12 per minue, and a pneumoperitoneal pressure of 14mmHg. The position of the head was low, and the feet were high with an inclination of 40°.

After the completion of tracheal intubation, patients in group B underwent volume-controlled breathing before pneumoperitoneum as in the control group, and after pneumoperitoneum, they were switched to PCV-VG and the ventilation parameters were set individually according to the pre-pneumoperitoneum P-V curves, with tidal volume 5-10ml/kg, respiratory rate 10-15 per minute, pneumoperitoneum pressure 10-13mmHg, and the posture of head-low-feet-high tilt of 15-30°. Intraoperatively, SpO_2 was ≥98% for all patients, and the end-tidal carbon dioxide partial pressure ($PetCO_2$) was maintained at 35-45mmHg.

The main observational indices were Ppeak and mean arterial pressure (MAP) at each time point after tracheal intubation, after pneumoperitoneum, and after postural position in both the groups.

Secondary observation indices included $PetCO_2$, tidal volume, respiratory rate, intraoperative pneumo-peritoneum pressure, head-down tilt, and patients' postoperative comfort scores at each time point in both groups. The comfort score was based on Kolcaba's Simple Comfort Scale,[13] which assessed the patients using 4 dimensions: environmental comfort, psychological comfort, physiological comfort, and socio-cultural comfort. Each dimension was scored 0-100, with a higher score indicating a higher comfort level.[14]

Data was analysed using SPSS 22. Data was expressed as mean±standard deviation or as frequencies and percentages, as appropriate. Independent t-test, chi-squared test, Fisher's exact test, and repeated measures analysis of variance (ANOVA) were used as appropriate. The level of statistical significance was set at $p<0.05$.

Results

Of the 200 patients, 40(20%) were cases of laparoscopy myomectomy, 152(76%) cases of ovarian cystectomy, and 8(4%) cases of hysterectomy. There were 100(50%) females

in group A with a mean age of 43.15±4.24 years, and 100(50%) were in group B with a mean age of 42.69±4.01 years (p=0.12) (Table 1).

Ppeak and MAP values were comparable in the groups after tracheal intubation (p>0.05). However, after pneumoperitoneum and postural positioning, they were significantly lower in group A than in group B (Table 2).

The difference in tidal volume and respiratory rate between the groups after tracheal intubation was not significant (p>0.05), but the tidal volume of the patients in group A after pneumoperitoneum and post-positioning was significantly lower than that of group B (p<0.05). The respiratory rate was considerably higher in group A than in group B (p<0.05). There was no marked difference in the $PetCO_2$ levels of the groups (p>0.05) (Table 3).

Intraoperative pneumoperitoneum pressure and head-down tilt were significantly lower in group A compared to group B(p<0.05) (Table 4).

The postoperative comfort score of patients in group A was 362.68±12.41 compared to 348.46±11.63 in group B (p<0.001) (Table 5).

Table-1: Intergroup comparison of general data.

Group	n	Age (year)	BMI (kg/m^2)	ASA level I/II
Control Group	100	42.69±4.01	28.17±0.43	75/25
Study Group	100	43.15±4.24	28.23±0.37	79/21
t/χ^2 value		0.79	1.06	0.45
p-value		0.12	0.28	0.50

BMI: Body Mass Index, ASA: American Society of Anaesthesiologists.

Table-2: Intergroup comparison of peak airway pressure and mean arterial pressure.

Group	n	Post-Intubation	Post-Traumatic Stress	Post-Position
peak airway pressure (Ppeak cmH_2O)				
Control group	100	20.23±1.54	28.17±1.36	31.30±1.44
Study group	100	19.86±1.67	25.70±1.22	27.69±1.01
t-test		1.63	13.52	20.52
p-value		0.87	（2.2e-16）＜0.001	（2.2e-16）＜0.001
Mean arterial pressure (MAP mmHg)				
Control group		112.26±8.90	123.69±8.72	125.64±7.95
Study group		110.88±8.33	117.66±8.16	119.99±8.30
t-test		1.13	5.05	4.91
p-value		0.06	7.653e-13	2.529e-09

Table-3: Intergroup comparison of tidal volume, respiratory rate and end-tidal carbon dioxide partial pressure ($PetCO_2$).

Group	n	Post-Intubation	Post-Traumatic Stress	Post-Position
Tidal volume (VT ml)				
Control group	100	491.0±32.4	490.0±30.0	489.2±28.6
Study group	100	487.2±32.1	456.3±29.4	454.0±28.4
t-test		0.83	8.02	8.73
p-value		0.23	2.2e-16	2.2e-16
Respiratory rate (f times/min)				
Control group	100	11.95±0.48	11.87±0.62	11.80±0.60
Study group	100	11.84±0.55	13.40±0.80	13.73±1.06
t-test		1.51	15.12	15.85
p-value		0.81	2.2e-16 ＜0.001	2.2e-16 ＜0.001
$PetCO_2$ (mmHg)				
Control group	100	36.84±0.32	38.55±0.41	41.36±0.53
Study group	100	36.90±0.38	38.62±0.43	41.25±0.46
t-test		1.21	1.18	1.57
p-value		1	0.52	0.99

Table-4: Intergroup comparison of intra-abdominal pressure and head-down tilt results.

Groups	n	Intra-abdominal Pressure (mmHg)	Head-down/ Foot-up tilt degree
Control group	100	13.96±0.55	39.7±5.3
Study group	100	11.03±0.84	29.8±5.6
t-test		29.18	12.84
p-value		<0.001	<0.001

Table-5: Intergroup comparison of postoperative Kolcaba scale scores.

Group	n	Pneumoperitoneum Pressure (mmHg)
Control group	100	348.46±11.63
Study group	100	362.68±12.41
t-test		8.36
p-value		<0.001

Discussion

The current findings confirm earlier observations. A study[14] showed that pneumoperitoneum and altered positioning improved respiratory dynamics during laparoscopic cholecystectomy. Wang et al.[16] demonstrated the benefits of using PCV-VG during laparoscopic surgery in elderly patients. A systematic review by Zou et al[17] also confirmed that PCV-VG during laparoscopic surgery improves patients' respiratory mechanics and oxygenation parameters compared to traditional ventilation strategies.

Laparoscopic surgery requires the establishment of a CO2 artificial pneumoperitoneum, which can lead to increased intra-abdominal and thoracic pressures in patients, causing a decrease in pulmonary compliance, affecting the pulmonary ventilation/blood flow ratio, and, in severe cases, leading to lung injury.[18,19] Studies have shown that intraoperative position can adversely impact a patient's respiratory, circulatory and neurological systems, increasing airway pressure, decreasing the volume of returned blood, affecting cerebrovascular autoregulation function, and increasing intracranial pressure.[20-22] These effects are more pronounced in obese patients.[23,24] In recent years, the beneficial effect of individualised

protective ventilation mode on lung tissue has received widespread attention. Studies show that PCV-VG mode, which provides decelerated airflow through constant pressure, and uses minimal positive pressure for preset tidal volumes, not only reduces airway and alveolar damage caused by high airway pressure, but also ensures effective alveolar ventilation and exchanges.[10,25] Based on the P-V curve, it is plausible that the procedure could be performed with less pneumoperitoneal pressure and less head-down tilt angle in the PCV-VG mode, thus reducing the adverse effects of pneumoperitoneal pressure and posture on the obese patient.

The current results showed that Ppeak and mean meritorious pulse pressure were higher in both groups after pneumoperitoneum and after head-down positioning than before pneumoperitoneum, suggesting that laparoscopic pneumoperitoneum and head-down position in obese patients have a significant effect on respiration and circulation. Ppeak and MAP were significantly lower after pneumoperitoneum and after head-down positioning, as well as pneumoperitoneum pressure and head-down tilt in the study group patients compared to the control group. It is possible that this effect was due to the use of PCV-VG ventilation mode in the study group. Under this mode of ventilation, intraoperative tidal volume was lower, and respiratory rate was higher in the study group, but the difference in $PetCO_2$ at all time points was not statistically significant when compared with the control group. Therefore, the current results suggest that a roving nurse can reduce the effects of mechanical ventilation on the patient's respiratory and circulatory systems by decreasing the pneumoperitoneum pressure and tilting the patient's head down to his/her feet without interfering with the surgeon's operation.

CO2 residue after laparoscopy can irritate the subphrenic nerve, resulting in subcostal and shoulder pain in most patients after surgery.[26] Indeed, postoperative subcostal and shoulder pain is considered one of the leading causes of reduced patient comfort.[27] In the present study, patients in the intervention group were operated upon with a lower pneumoperitoneum pressure, which reduced postoperative CO_2 residuals. A smaller tilt angle was also used, which reduced shoulder compression by the shoulder rest. Together, this reduced the severity of postoperative pain and improved patient comfort scores.

The current study has some limitations, like its retrospective design, which may have introduced a bias in its findings. Additionally, the selected patients were operated upon by different medical teams (surgeons, anaesthetists, theatre nurses), and the postoperative Kolcaba scale scores were done by different nurses, which may have impacted the findings. Further high-quality studies are needed to verify the current findings.

Conclusion

The individualised use of PCV-VG ventilation mode based on the P-V curve could guide the regulation of pneumoperitoneum pressure and position during laparoscopy, and was more efficient in stabilising haemodynamic, reducing postoperative complications, and improving postoperative comfort in obese patients.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: The Provincial Department of Health, Zhejiang, China.

References

1. Wang J, Han Y. Status and influencing factors of postoperative comfort in patients with ovarian cysts after laparoscopic surgery. Chin J Mod Nursing 2022;28:1788-91. doi: 10.3760/cma.j.cn115682-20210924-04346
2. Arvizo C, Mehta ST, Yunker A. Adverse events related to Trendelenburg position during laparoscopic surgery: recommendations and review of the literature. Curr Opin Obstet Gynecol 2018;30:272-8. doi: 10.1097/GCO.0000000000000471
3. Kim K, Jang DM, Park JY, Yoo H, Kim HS, Choi WJ. Changes of diaphragmatic excursion and lung compliance during major laparoscopic pelvic surgery: A prospective observational study. PLoS One 2018;13:e0207841. doi: 10.1371/journal.pone.0207841
4. Parameswaran K, Todd DC, Soth M. Altered respiratory physiology in obesity. Can Respir J 2006;13:203-10. doi: 10.1155/2006/834786
5. Melo LC, Silva MAM da, Calles AC do N. Obesity and lung function: a systematic review. Einstein (Sao Paulo) 2014;12:120-5. doi: 10.1590/s1679-45082014rw2691
6. Hodgson LE, Murphy PB, Hart N. Respiratory management of the obese patient undergoing surgery. J Thorac Dis 2015;7:943-52. doi: 10.3978/j.issn.2072-1439.2015.03.08
7. De Jong A, Wrigge H, Hedenstierna G, Gattinoni L, Chiumello D, Frat JP, et al. How to ventilate obese patients in the ICU. Intensive Care Med 2020;46:2423-35. doi: 10.1007/s00134-020-06286-x
8. Martinez BP, Silva JR, Silva VS, Gomes Neto M, Forgiarini Júnior LA. Influence of different body positions in vital capacity in patients on postoperative upper abdominal. Braz J Anesthesiol 2015;65:217-21. doi: 10.1016/j.bjane.2014.06.002
9. Xu M, Zhang J, Zhao W, Fang B. Application of positive end-expiratory pressure of pulmonary protective ventilation strategy in laparoscopic surgery in overweight patients. J Chin Physician 2020;22:674-82. doi: 10.3760/cma.j.cn431274-20190320-00302
10. Jain D, Claure N, D'Ugard C, Bello J, Bancalari E. Volume Guarantee Ventilation: Effect on Preterm Infants with Frequent Hypoxemia Episodes. Neonatology 2016;110:129-34. doi: 10.1159/000444844
11. NCSS Statistical Software. PASS 2023: Power Analysis & Sample Size, Version: 15.0.13. [Online] 2020 [Cited 2025 February 13]. Available from URL: https://www.ncss.com/download/pass/updates/pass15/
12. Irlbeck T, Zwißler B, Bauer A. ASA classification: Transition in the course of time and depiction in the literature. Anaesthesist 2017;66:5-10. doi: 10.1007/s00101-016-0246-4
13. Kolcaba K. Comfort Theory and Practice: A Vision for Holistic Health Care and Research. New York, USA: Springer Publishing Company;

2003.

14. Yu Q, Wang X, Zhou F. The effect of curved supine position management combined with multimodal pain intervention on the incidence of stress injury and comfort in postoperative orthopaedic patients. Int J Nurs 2024;43:158-62. doi: 10.3760/cma.j.cn221370-20221117-00039
15. Kothari A, Baskaran D. Pressure-controlled Volume Guaranteed Mode Improves Respiratory Dynamics during Laparoscopic Cholecystectomy: A Comparison with Conventional Modes. Anesth Essays Res 2018;12:206-12. doi: 10.4103/aer.AER_96_17
16. Wang P, Zhao S, Gao Z, Hu J, Lu Y, Chen J. Use of volume controlled vs. pressure controlled volume guaranteed ventilation in elderly patients undergoing laparoscopic surgery with laryngeal mask airway. BMC Anesthesiol 2021;21:69. doi: 10.1186/s12871-021-01292-y
17. Zou T, Sun S, Wu Y, Yin Q, Yang D. Lung Protection of Mechanical Ventilation during Laparoscopic Surgery: A Systematic Review. Journal of Anesthesia and Translational Medicine (JATM) 2022;1:1-5. doi: 10.58888/2957-3912-20220101
18. Liao CC, Kau YC, Ting PC, Tsai SC, Wang CJ. The Effects of Volume-Controlled and Pressure-Controlled Ventilation on Lung Mechanics, Oxidative Stress, and Recovery in Gynecologic Laparoscopic Surgery. J Minim Invasive Gynecol 2016;23:410-7. doi: 10.1016/j.jmig.2015.12.015
19. Talizin TB, Tsuda MS, Tanita MT, Kauss IAM, Festti J, Carrilho CMD de M, et al. Acute kidney injury and intra-abdominal hypertension in burn patients in intensive care. Rev Bras Ter Intensiva 2018;30:15-20. doi: 10.5935/0103-507x.20180001
20. Klauschie J, Wechter ME, Jacob K, Zanagnolo V, Montero R, Magrina J, et al. Use of anti-skid material and patient-positioning to prevent patient shifting during robotic-assisted gynecologic procedures. J Minim Invasive Gynecol 2010;17:504-7. doi: 10.1016/j.jmig.2010.03.013
21. Matanes E, Weissman A, Rivlin A, Lauterbach R, Amit A, Wiener Z, et al. Effects of Pneumoperitoneum and the Steep Trendelenburg Position on Heart Rate Variability and Cerebral Oxygenation during Robotic Sacrocolpopexy. J Minim Invasive Gynecol 2018;25:70-5. doi: 10.1016/j.jmig.2017.07.009
22. Peng P, Zhu J, Gui B, Ma R. Transperitoneal versus extraperitoneal robot-assisted laparoscopic radical prostatectomy: a prospective study of perioperative atelectasis by lung ultrasound. Int J Anesth Resusc 2017;38:978-82. doi: 10.3760/cma.j.issn.1673-4378.2017.11.005
23. Zhao L, Jiang W. The advance of perioperative ventilation strategy in obese patients. Int J Anesth Resusc 2009;30:73-6. doi: 10.3760/cma.j.issn.1673-4378.2009.01.020
24. Phong SVN, Koh LKD. Anaesthesia for robotic-assisted radical prostatectomy: considerations for laparoscopy in the Trendelenburg position. Anaesth Intensive Care 2007;35:281-5. doi: 10.1177/0310057X0703500221
25. Keszler M, Abubakar K. Volume guarantee ventilation during surgical closure of patent ductus arteriosus. Am J Perinatol 2015;32:23-6. doi: 10.1055/s-0034-1371713
26. Neogi P, Kumar P, Kumar S. Low-pressure Pneumoperitoneum in Laparoscopic Cholecystectomy: A Randomized Controlled Trial. Surg Laparosc Endosc Percutan Tech 2020;30:30-4. doi: 10.1097/SLE.0000000000000719
27. Zhou Y, Han W. Efficacy of deep neuromuscular blockade combined with low-pressure pneumoperitoneum for gynecological laparoscopic surgery in obese patients. Chin J Anesthesiol 2019;39:722-5. doi: 10.3760/cma.j.issn.0254-1416.2019.06.022

Author Contribution:

Z: Conceived, design, writing and drafting.
GF & QZ: Data collection and performed data analysis.
YR: Data collection, performed data analysis and editing.