

A randomized controlled trial comparing of volume controlled and pressure-regulated volume controlled ventilation in patients undergoing laparoscopic gynecological surgery under general anesthesia

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Abstract

Background: Adjustment of ventilatory settings and ventilatory mode in laparoscopic gynecologic surgery for improved mechanical ventilation performance during anesthesia is important. **Objectives:** To quantify and compare the effects of volume controlled ventilation (VCV) with pressure regulated volume control (PRVC) on respiratory mechanics in patient undergoing laparoscopic gynecological surgery. **Methods:** This study is a randomized controlled trial in 32 patients who were scheduled for elective gynecological laparoscopic surgery with general anesthesia. All patients were randomly allocated to 2 groups using volume controlled (group VCV, n = 16) or pressure regulated volume controlled ventilator mode (group PRVC, n = 16) under general anesthesia. Various respiratory parameters were measured at 10 min after induction and 30, 60, and 120 after Trendelenburg positioning. A Shapiro–Wilk test was used to determine distribution normality. A student t test was

used to compare continuous data between study groups and a repeated measures ANOVA was used to compare all interval data. **Results:** There were no significant differences in demographic data between groups. Between the groups there were significant differences in heart rate and at 10 min after induction, and heart rate and peak airway pressure 30, 60, and 120 min after Trendelenburg positioning ($P < 0.05$). However, there were no significant differences in blood pressure, minute ventilation, and dynamic compliance between the groups. **Conclusion:** PRVC is a safe alternative choice for laparoscopic gynecologic surgery because of lower peak airway pressure that might lower the risk of lung injury compared with VCV.

Keywords: peak airway pressure, volume controlled ventilation, pressure regulated volume controlled ventilation, gynecological laparoscopic surgery

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การเปรียบเทียบประสิทธิภาพการใช้ volume controlled กับ pressure-regulated volume controlled ventilation ในผู้ป่วยที่ได้รับการระงับความรู้สึกแบบทั่วตัวเพื่อผ่าตัดส่องกล้องทางนรีเวช

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บทคัดย่อ

ความเป็นมา: การผ่าตัดส่องกล้องทางนรีเวช ผู้ป่วยจำเป็นต้องได้รับการระงับความรู้สึกแบบทั่วตัว และมีการเปลี่ยนแปลงของระบบทั่วร่างกายมากกว่า การผ่าตัดแบบเปิดหน้าท้อง การปรับและเลือกช่วยหายใจในผู้ป่วยระหว่างการผ่าตัดจึงเป็นสิ่งที่สำคัญ เพื่อช่วยลดภาวะแทรกซ้อนจากการผ่าตัด

วัตถุประสงค์: เพื่อเปรียบเทียบประสิทธิภาพในด้านระบบทางเดินหายใจ ระหว่างการใช้ volume controlled กับ pressure-regulated volume controlled ventilation ในผู้ป่วยที่ได้รับการระงับความรู้สึกแบบทั่วตัวเพื่อผ่าตัดส่องกล้องทางนรีเวช

วิธีการศึกษา: การศึกษาแบบ randomized controlled trial ศึกษาผู้ป่วยเพศหญิงที่มีอายุตั้งแต่ 20-60 ปี ที่มารับการระงับความรู้สึกแบบทั่วตัวเพื่อผ่าตัดส่องกล้องทางนรีเวช ณ ห้องผ่าตัด โรงพยาบาลรามาธิบดี จำนวน 32 ราย โดยจะใช้วิธีสุ่มเลือกผู้ป่วยออกเป็น 2 กลุ่ม ได้แก่ กลุ่มที่ได้รับการช่วยหายใจแบบ volume controlled ventilation (VCV) จำนวน 16 ราย และกลุ่มที่ได้รับการช่วยหายใจแบบ pressure regulated volume controlled ventilation (PRVC) จำนวน 16 ราย บันทึกค่าพารามิเตอร์ทางเดินหายใจต่างๆ ที่เวลา 10 นาที หลังจากเริ่มให้การระงับความรู้สึก และที่เวลา 30, 60 และ 120 นาที หลังจากจัดทำศีรษะต่ำ (Trendelenburg positioning) วิเคราะห์

ข้อมูลโดยใช้โปรแกรมสำเร็จรูป ด้วยสถิติ student t test และ ANOVA ผลการศึกษา: ไม่มีความแตกต่างอย่างมีนัยสำคัญในด้านข้อมูลประชากรของทั้ง 2 กลุ่ม กลุ่มที่ได้รับการช่วยหายใจ แบบ PRVC รักษาระดับความดันสูงสุดในทางเดินหายใจ (peak airway pressure) ได้ดีกว่ากลุ่ม VCV อย่างมีนัยสำคัญ ($P < 0.05$) ตลอดช่วงเวลานาทีที่ 30, 60 และ 120 หลังจากจัดทำศีรษะต่ำ นอกจากนี้ กลุ่ม PRVC ยังมีการเปลี่ยนแปลงของอัตราการเต้นของหัวใจที่มากกว่ากลุ่ม VCV ตลอดทุกช่วงเวลา อย่างไรก็ตามไม่มีความแตกต่างในด้านความดันเลือด minute ventilation และ dynamic compliance ของทั้ง 2 กลุ่มอย่างมีนัยสำคัญ

สรุป: การช่วยหายใจแบบ PRVC ในผู้ป่วยที่ได้รับการระงับความรู้สึกแบบทั่วตัวเพื่อผ่าตัดส่องกล้องทางนรีเวช เป็นทางเลือกที่ปลอดภัยและมีประสิทธิภาพดี เมื่อเทียบกับการช่วยหายใจแบบ VCV ในด้านการช่วยลดความดันสูงสุดในทางเดินหายใจซึ่งอาจจะทำให้ช่วยลดความเสี่ยงของการได้รับบาดเจ็บที่ปอด

คำสำคัญ: ความดันสูงสุดในทางเดินหายใจ, การระงับความรู้สึกแบบทั่วตัว, การผ่าตัดส่องกล้องทางนรีเวช, volume controlled ventilation, pressure regulated volume controlled ventilation

Introduction

Laparoscopic surgery has been used in gynecological procedures. It is associated with reduced morbidity and hospital stay. Laparoscopic surgery decreases functional residual capacity and respiratory compliance and increases airway pressure because of limited diaphragmatic movements by the pneumoperitoneum and further by the Trendelenburg position.¹ As a consequence, adjustment of ventilator settings during laparoscopic surgery must be monitored.

The conventional volume controlled ventilation (VCV) mode is generally preferred because anesthesiologists are familiar with it. However, with constant flow rates, VCV tends to create more airway pressure intraoperatively compared with pressure-controlled ventilation (PCV) and might increase the risk of lung injury. Previous studies^{2,3} have shown potential advantages of PCV over VCV during laparoscopic surgery, such as lower airway pressure and higher compliance. Although PCV mode ventilation may provide greater control over airway pressure than VCV mode, it could result in hypoventilation and volume trauma because of inconsistency of intrathoracic and intra-abdominal pressures during laparoscopic surgery.

Pressure-regulated volume control (PRVC) is a new mode of ventilation that combines the advantages of decelerating inspiratory flow pattern of PCV mode with the ease of using the VCV mode.⁴ PRVC could thus be beneficial in this type of surgery. Guldager et al.⁴ conducted a study and compared VCV and PRVC in acute respiratory failure and found that

peak inspiratory pressure was significantly lower during PRVC ventilation than during VCV with the same tidal volume. Currently, studies of PRVC in the operating theatre are limited. The objective in this study was to compare peak airway pressure between VCV mode and the alternative mode PRVC and other effects on respiratory mechanics in patients undergoing laparoscopic gynecological surgery.

Methods

This study was undertaken at the Faculty of Medicine, Ramathibodi Hospital, Mahidol University. All women undergoing laparoscopic gynecological surgery, aged 20 to 60 years, with American Society of Anesthesiologists physical status I to III, were invited to participate. All patients were free of cardiac, pulmonary, hepatorenal, and neuromuscular disease. Patients with body mass index (BMI) $> 30 \text{ kg/m}^2$ were not included in the study. Participation was voluntary, and informed written consent was obtained from all participants. The study protocol was approved by the Ethical Clearance Committee, Faculty of Medicine, Ramathibodi Hospital, Mahidol University (No.11-51-36).

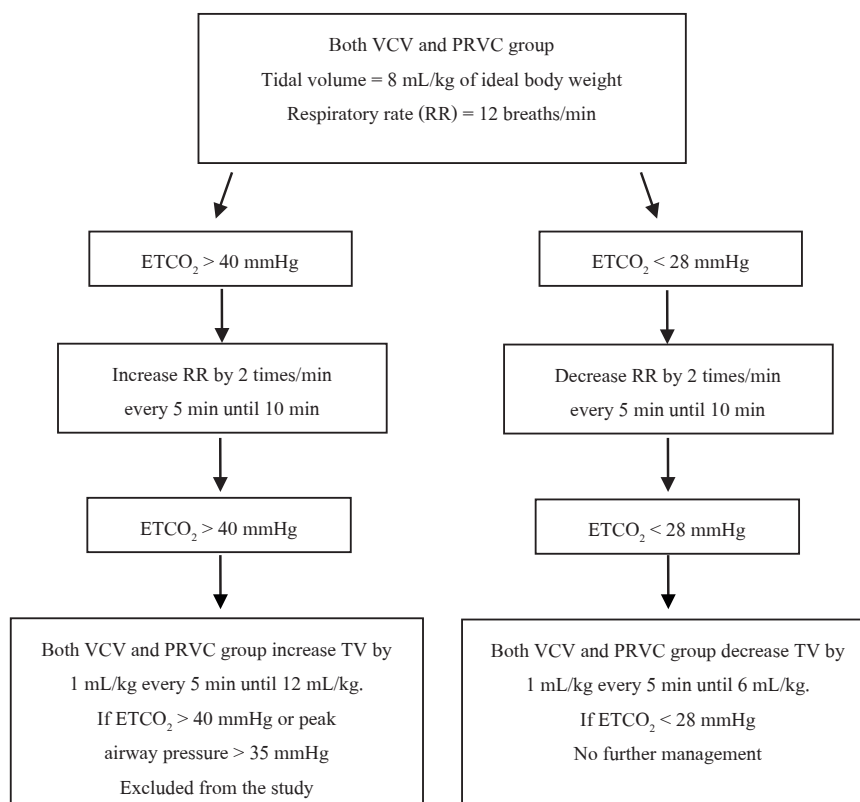
After patient transfer to the operating theater, monitoring consisting of electrocardiography, noninvasive blood pressure, pulse oximetry, and capnometry was initiated. After preoxygenation, anesthesia was induced with propofol 2 mg/kg and fentanyl 1 $\mu\text{g/kg}$. Tracheal intubation using a cuffed 7.5-mm internal diameter endotracheal tube of proper size was facilitated with cis-atracurium, 0.2 mg/kg, as a neuromuscular blocking agent.

Mechanical ventilation was then performed. Anesthesia was maintained with sevoflurane in a 50% oxygen–air mixture. Patients were randomly allocated to 1 of 2 groups of 16 patients each by using computer-generated random numbers. Ventilation mode was maintained in the VCV group and the PRCV group. In both groups, respiratory rate was set to 12 breaths per minute during anesthesia. We used an inspiratory–expiratory ratio of 1:2, with an inspiratory pause equal to 25% of inspiratory time. Both PRVC and VCV initiated a tidal volume of 8 mL/kg of ideal body weight, and we adjusted the ventilator setting following a protocol that kept end-tidal CO₂ (ETCO₂) between 28 to 40 mmHg.

In all patients, CO₂ pneumoperitoneum was administered with an intra-abdominal pressure of

10 to 12 mmHg. Then the Trendelenburg position was established. During the laparoscopic surgery, the hemodynamic variables consisting of heart rate, blood pressure (systolic, diastolic, and mean arterial pressure), and ventilatory variables consisting of tidal volume, minute ventilation, respiratory rate, peak airway pressure, dynamic compliance, oxygen saturation, and ETCO₂ tension were monitored and data were recorded 4 times: 10 minutes after induction in the supine position (T1), 30 minutes after pneumoperitoneum in the Trendelenburg position (T2), and 60 minutes after pneumoperitoneum in the Trendelenburg position (T3) and 120 minutes after pneumoperitoneum in the Trendelenburg position (T4). Dynamic compliance was calculated as exhaled tidal volume divided with peak airway pressure.

Figure 1 Algorithm for intra operative protocol



Statistical analysis

Statistical analyses were conducted using IBM SPSS for Windows, version 20.0. A Shapiro–Wilk test was used to test for normal distribution of continuous data. A student t test was used to compare continuous data. A repeated measures ANOVA was used to determine differences in interval data between the two groups. Sample size calculation was based on a previous study¹ that compared the effects of pressure-controlled ventilation and volume controlled ventilation in robot-assisted laparoscopic radical prostatectomy. The investigators found a significant difference in peak airway pressure, Trendelenburg positioning, and pneumoperitoneum 60 min between the PCV and VCV groups (PCV 29.2 ± 5.0 , where VCV 34.0 ± 3.5 cmH₂O). According to a power analysis using 2 independent groups, and after adding 10% to avoid data loss, we determined that 16 patients were needed in each group to provide sufficient power (power 80% and α 0.05) to conduct the study.

Results

Thirty-two women were included in this study with 16 patients per group. The patient demographic data were comparable between the groups (Table 1). The body weight and height in the VCV group was higher than in the PRVC group, but body mass index (BMI) was not significantly different between the groups. The baseline data, minute ventilation, and ET CO_2 were not significantly different between the two groups. For the hemodynamic variables (Table 2), we found only heart rate was significantly different at all times, while the other variables were not significantly different.

PRVC was associated with lower peak airway pressure at 30, 60, and 120 minutes after pneumoperitoneum. Dynamic compliance tended to be slightly higher in the PRVC group than in the VCV group although the difference was not significant (Table 3, 4, and 5). Tidal volume was similar in PRVC and VCV groups at 60 and 120 minutes after pneumoperitoneum. However, at 10 minutes after induction and 30 minutes after pneumoperitoneum, tidal volume was significantly decreased in patients in the PRVC group compared with those in the VCV group.

Table 1. Demographic data

	VCV group (n = 16)	PRVC group (n = 16)	P
Age (yrs)	40.7 $\pm$ 9.76	35.0 $\pm$ 12.12	0.15
Body weight (kg)	58.4 $\pm$ 8.33	52.1 $\pm$ 8.27	0.04*
Height (cm)	160.4 $\pm$ 4.67	156.1 $\pm$ 5.83	0.03*
Body mass index (kg/m ²)	23.0 $\pm$ 3.11	21.4 $\pm$ 3.84	0.15
Degree of Trendelenburg	20.8 $\pm$ 7.97	23.4 $\pm$ 7.79	0.31

Values are given as mean $\pm$ SD, * $P < 0.05$ = statistical significant, VCV = volume-controlled ventilation, PRVC = pressure regulated volume control

Table 2. Hemodynamic variables

	VCV Group (n = 16)	PRVC Group (n = 16)	P
Heart rate (bpm)			0.001*
10 min	63 ± 7.5	71 ± 10.8	0.041*
30 min	66 ± 8.7	76 ± 12.1	0.001*
60 min	64 ± 10.9	75 ± 13.7	0.010*
120 min	66 ± 8.9	75 ± 10.7	0.024*
Systolic blood pressure (mmHg)			
10 min	102.4 ± 8.37	104.2 ± 16.99	0.44
30 min	123.0 ± 23.49	113.8 ± 6.90	0.39
60 min	117.4 ± 15.66	111.7 ± 9.42	0.31
120 min	114.2 ± 10.32	114.7 ± 10.29	0.90
Diastolic blood pressure (mmHg)			
10 min	64.7 ± 8.78	59.7 ± 8.63	0.81
30 min	72.6 ± 8.76	67.4 ± 8.65	0.15
60 min	68.2 ± 9.30	65.8 ± 4.71	0.97
120 min	70.6 ± 9.13	67.1 ± 8.19	0.32

Values are given as mean ± SD, *P < 0.05 = statistical significant, VCV = volume-controlled ventilation, PRVC = pressure regulated volume control, bpm = beats per minute

Table 3. Ventilatory variables

	VCV group (n = 16)	PRVC group (n = 16)	P
Tidal volume (mL)			<0.03*
10 min	457.1 ± 47.85	425.0 ± 52.22	0.03*
30 min	448.9 ± 49.97	420.8 ± 39.65	0.04*
60 min	449.9 ± 51.80	420.8 ± 39.65	0.052
120 min	455.9 ± 49.79	422.9 ± 36.08	0.07
Minute ventilation (L/min)			
10 min	5.2 ± 0.64	5.6 ± 1.26	0.95
30 min	5.8 ± 1.30	6.1 ± 1.04	0.93
60 min	6.0 ± 1.35	6.5 ± 0.91	0.84
120 min	6.4 ± 1.57	6.6 ± 0.91	0.61

Table 3. (cont.)

	VCV group (n = 16)	PRVC group (n = 16)	P
Peak airway pressure (cmH₂O)			0.009*
10 min	15.5 ± 2.40	13.8 ± 3.86	0.19
30 min	27.1 ± 5.36	22.8 ± 5.65	0.02*
60 min	27.0 ± 4.08	22.3 ± 3.73	0.001*
120 min	27.2 ± 5.37	22.4 ± 4.27	0.02*

Values are given as mean ± SD, **P* < 0.05 = statistical significant, VCV = volume-controlled ventilation, PRVC = pressure regulated volume control

Table 4. ETCO₂ and intra-abdominal pressure

	VCV group (n = 16)	PRVC group (n = 16)	P
ETCO₂ (mmHg)			<0.03*
10 min	27.6 ± 1.90	28.8 ± 3.35	0.09
30 min	37.5 ± 2.58	36.4 ± 1.73	0.95
60 min	36.4 ± 2.06	34.8 ± 3.96	0.47
120 min	36.2 ± 2.97	34.9 ± 2.02	0.24
Intra-abdominal pressure (mmHg)			
30 min	14.7 ± 0.65	14.5 ± 1.13	0.52
60 min	14.5 ± 1.17	14.3 ± 1.18	0.35
120 min	14.0 ± 1.48	14.5 ± 1.13	0.39

Values are given as mean ± SD, **P* < 0.05 = statistical significant, VCV = volume-controlled ventilation, PRVC = pressure regulated volume control, ETCO₂ = end-tidal carbondioxide

Table 5. Dynamic compliance

Variables	VCV group (n = 16)	PRVC group (n = 16)	P
Dynamic compliance (mL/cmH₂O)			0.009*
10 min	30.7 ± 5.38	31.9 ± 8.07	0.63
30 min	17.5 ± 4.04	19.7 ± 4.86	0.17
60 min	17.5 ± 3.74	19.9 ± 3.85	0.08
120 min	16.9 ± 3.03	19.4 ± 4.13	0.06

Values are given as mean ± SD, **P* < 0.05 = statistical significant, VCV = volume-controlled ventilation, PRVC = pressure regulated volume control

Discussion

In this study, there were significant differences in peak airway pressure at 30, 60, and 120 minutes after Trendelenburg positioning in patients undergoing laparoscopic gynecological surgeries. The dynamic compliance in the PRVC group tended to be better than in the VCV group, but was not significantly different. This might be because this study was not adequately powered to detect changes in dynamic compliance.

Raised intra-abdominal pressure by pneumoperitoneum and alteration of the patient's position (Trendelenburg) during laparoscopic gynecological surgery can cause a significantly increased peak airway pressure. VCV-anesthetized patients have an increase in airway pressure and lower lung compliance compared with PCV.³ Decelerating flow patterns of PCV provide a more homogenous gas distribution, reduce peak airway pressure, and improve gas exchange. Although PRVC and PC ventilation modes have the same decelerating inspiratory flow, PRVC is an easier mode of ventilation as it offers adjustment of inspiratory pressure from breath to breath based on compliance calculation from the pressure plateau to target a set tidal volume.

Decelerating flow patterns have been found in patients who have high airway pressure. These findings were well documented in many previous studies.³⁻¹⁰ In patients with acute lung injury,⁵⁻⁶ PCV could reduce lung strain and lung injury associated with increased peak airway pressure in VCV mode. In laparoscopic gynecological surgery, Ogurlu et al.³ found that PCV could provide sufficient minute ventilation ensuring

adequate CO₂ removal and improved oxygenation, while using a lower plateau pressure than VCV. They concluded that both VCV and PCV seemed to be equally suitable. Other studies in obese patients undergoing laparoscopic surgery had variable results. Cadi et al.⁷ reported that PRCV provided better lung oxygenation than VCV by enhancing alveolar recruitment in patients with BMI >35 kg/m². By contrast, Hans and De Baerdemaeker et al.^{8,9} found that when compared with patients in a VCV group, patients with PCV had lower peak airway pressure, but there was no difference in enhancement of oxygenation. This could be explained by different respiratory mechanics in obese patients compared with patients of normal weight. Joanna M Dion, et al.¹³ found that PCV-VG and PC ventilation could provide lower peak airway pressure and higher compliance compared with VCV group during laparoscopic-assisted bariatric surgery.

Furthermore, the study of Samantory¹⁴ showing that PRVC may be superior to PCV mode in patients after cardiac surgery by reducing intrapulmonary shunts and improving oxygenation after cardiopulmonary bypass-induced perfusion mismatch.

We found that PRVC is beneficial in maintaining adequate ventilation with lower peak airway pressure and with increased dynamic lung compliance compared with VCV. Therefore PRVC might be a suitable mode of ventilation for patients undergoing laparoscopic gynecological surgery, whereas the pneumoperitoneum and the Trendelenburg position can cause an elevated diaphragm and decrease the functional residual capacity and lung compliance.

We were not able to show effects of barotraumas and had no intraoperative complications, such as pneumothorax, lung injury, and hypoxemia, possibly because peak airway pressure in both groups did not exceed 35 mmHg. Intraoperative hemodynamic variables were similar in both groups except for slightly higher heart rates in the PRVC group. This may be related to the small change in mean airway pressure.¹¹ Unfortunately, the data obtained in this study were not sufficient to completely interpret these findings. However, Balick-Weber et al.¹² evaluated the cardiovascular consequences of PCV and VCV mode in patients undergoing laparoscopic urological surgery using transesophageal echocardiography. The authors found that PCV and VCV had statistically similar effects on hemodynamic parameters despite a significant increase in the mean airway pressure with PCV mode when the patients were in a 20° Trendelenburg position.

Conclusion

PRVC mode ventilation is a safe alternative for laparoscopic gynecological surgery because of lower peak airway pressure that might improve oxygenation and lower risk to lung injury compared with VCV mode ventilation. Further study to compare PRVC and VCV ventilation in more subjects with equipment to determine precise oxygenation data is warranted to extend our findings.

Conflict of interest disclosure

The authors have no conflicts of interest to declare.

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