

Original Article

Comparison of three ventilatory modes during one-lung ventilation in elderly patients

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Abstract: Objective: The purpose of this study was to explore the effects of three different ventilatory modes: volume controlled ventilation (VCV), pressure controlled ventilation (PCV) and pressure controlled ventilation-volume guaranteed (PCV-VG) on arterial oxygenation and airway pressure during one-lung ventilation (OLV) in elderly patients. **Methods:** We enrolled 66 patients who underwent thoracic surgery requiring at least 1 hour of OLV and aged above 65 years into the study. Patients were classified into VCV, PCV and PCV-VG groups according to a controlled, randomized design. Patients were ventilated to obtain a tidal volume (TV) of 8 mL/kg with three different ventilatory modes during OLV. The Hemodynamic and respiratory data had been recorded during intraoperation and arterial blood gases were obtained at baseline, 20, 40, 60 minutes after OLV, end of surgery. **Results:** Compared with VCV group, Ppeak was significantly lower in PCV and PCV-VG group ($P<0.05$), and the difference was not found between the PCV and PCV-VG group. PaO₂ in PCV and PCV-VG group were higher than VCV group after the point of OLV+40 ($P<0.05$). Comparison of PCV group, PaO₂ in PCV-VG group was higher, but did not show a significantly improved during OLV ($P>0.05$). **Conclusions:** Compared with VCV, the use of PCV and PCV-VG have a significant advantage in intraoperative oxygenation and airway pressure for elderly patients undergoing OLV.

Keywords: Volume controlled ventilation, pressure controlled ventilation, pressure controlled ventilation volume guaranteed, aged, one-lung ventilation

Introduction

One-lung ventilation (OLV) has been considered the essential method for the thoracic surgery. However the prevention of arterial hypoxemia and acute lung injury (ALI) is still the major concerns during OLV in anesthesiologists [1], especially for elderly patients [2-4]. Elderly people have potentially physical hypoxemia because of the degeneration of respiratory system and the decreasing of respiratory function [5, 6]. The physical changes of pulmonary function in elderly patients are associated with the high risk of intraoperative lung injury and postoperative mortality and morbidity [7, 8]. Volume controlled ventilation (VCV) and pressure controlled ventilation (PCV) are the common ventilatory modes during OLV undergoing thoracic surgery. A controversy outcome has been shown as to which ventilation mode is better for intraoperative and postoperative arterial oxygenation during OLV [9-15]. The VCV mode can ensure the stabilization of minute ventilation

volume, however, the higher peak inspiratory pressures may increase the incidence of barotrauma and the nonuniform gas distribution. The PCV mode has been found some advantages in improving arterial oxygenation and rapidly decelerating flow pattern, but some studies suggested that the initial high peak inspiratory flow rates still might lead to lung injury through traction forces on the lung tissue and alveoli [16], therefore the changes of lung compliance in patients can give rise to the unstable minute ventilation volume.

Pressure controlled ventilation volume guaranteed (PCV-VG) is a new ventilation mode that has been utilized in field of anesthesiology. PCV-VG mode will deliver the preset tidal volume with the lowest possible pressure using a decelerating flow, which have the efficiency and clinical benefits of PCV, yet still compensate for the changes in patient's lung compliance. Although there are few studies on the PCV-VG ventilation mode at present, especially in OLV,

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Table 1. Preoperative demographic characteristics of the patients

	VCV (n=22)	PCV (n=21)	PCV-VG (n=21)
Age, Yr	70.2±5.2	69.7±4.5	72.2±5.9
Sex, M/F	14/8	13/8	14/7
Body weight, kg	59.1±9.4	61.0±10.5	62.1±9.3
Height, cm	164.3±8.8	163.7±9.3	168.3±9.6
BMI (kg/m ²)	25.1±4.3	26.3±6.6	24.5±5.9
Side (right/left) (n)	12/10	11/10	12/9
PaO ₂ (mmHg)	79.3±7.8	77.6±6.9	80.3±8.8
PaCO ₂ (mmHg)	44.3±6.1	43.8±4.7	42.3±6.5
Predicted FVC %	78.2±11.4	79.1±10.7	80.2±9.8
Predicted FEV ₁ %	73.9±8.0	74.2±9.6	75.0±10.1

Data are shown as mean ± SD. FEV₁=forced expiratory volume in 1 second; FVC=forced vital capacity; PaO₂=arterial blood oxygen tension; PaCO₂=arterial blood carbon dioxide tension. BMI=body mass index. *P<0.05 (1VCV v others periods).

the results of these studies are still controversial in the effects of arterial oxygenation during OLV compared with VCV [17-19].

The aim of our study is to investigate which ventilatory mode is more advantaged on arterial oxygenation and airway pressure during OLV in elderly patients.

Patients and methods

Study protocol

Approval of the protocol was granted by the ethics committee of Affiliated Tumor Hospital of Guangxi Medical University. A total of 66 patients were enrolled into the study undergoing thoracic surgery from October 2013 to September 2014 requiring at least 1 hour of OLV, ASA physical status I-III and aged above 65 years. Each patient or their nearest relatives need to sign the informed consent. No commercial entity had provided any device or equipment in this study. The exclusion criteria were previous thoracic surgery, uncompensated cardiac disease, hepatic or renal disease, asthma, tracheostomy state.

Before anesthetic induction, patients were classified into three groups (VCV, PCV, PCV-VG) according to a controlled, randomized design produced by computer-generated codes. After the patients went into the operating room, standard monitoring (noninvasive blood pressure, electrocardiogram, and pulse oximetry) had been

performed. Invasive arterial pressure and blood gas analysis had been monitored through inserting an arterial cannula into the radial artery. After induced by midazolam (0.04~0.06 mg/kg), propofol (1.0~1.5 mg/kg), fentanyl (3~4 µg/kg), and rocuronium (0.8~1.0 mg/kg), a left or right double lumen trachea (Mallinckrodt-Endobronchial Tube, Covidien, Made in Ireland) was intubated with no. 37 for male and no. 35 for female patients. Continuous infusion of remifentanyl (0.1~0.2 µg/kg/min), propofol (50~100 µg/kg/min) were used to maintain the depth of anesthesia, supplemental fentanyl and rocuronium were administered discontinuously as needed. No volatile anesthetics were used during the operation. Auscultation and fiberoptic bronchoscopy were performed to confirm the correct

position before and after changing the patient to a lateral decubitus position. The tube was connected to a Datex-Ohmeda Ventilator (Aestiva/57900, Madison, USA) and the nonventilated side was left open to the air during OLV. The ventilation strategy used a TV of 10 ml/kg during two-lung ventilation (TLV) and the goal exhaled TV was 8 mL/kg during OLV using VCV, PCV and PCV-VG ventilatory mode in three groups respectively. The inspiration-to-expiration ratio (I:E) was 1:2 and FIO₂ was 100% in all groups throughout the operative time. End-tidal carbon dioxide (ETCO₂) was maintained between 35 and 40 mmHg during OLV by adjusting the respiratory rate. During surgery, the exclusion criteria was that SpO₂ can't maintain above 90% after the treatments were performed, such as adjusting the catheter position, reconfirming by fiberoptic bronchoscopy, sucking sputum.

Compound Sodium Chloride Injection (SiChuan KeLun Pharmaceutical CO. LTD, China) and 6% HES 130/0.4 (Voluven®; Fresenius Kabi, Germany) were used to fluid replacement to maintain the stable arterial pressure. If mean arterial pressure was lower than 60mmHg continuous more than 5 min, repeated doses of 5 mg ephedrine were administered intravenous. All patients were transferred into intensive care unit (ICU) to extubation after surgery. The anesthesiologists who implemented the anesthesia were not taken part in the collection of the data.

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Table 2. Intraoperative data of the patients

	VCV (n=22)	PCV (n=21)	PCV-VG (n=21)
Duration of anesthesia (min)	163.0±33.8	160.6±36.4	158.0±41.5
Duration of surgery (min)	131.5±29.8	133.0±26.8	129.5±32.3
Duration of OLV (min)	98.6±34.8	101.0±30.9	97.8±28.8
blood loss (ml)	163±45	154±54	250±58
urine output (ml)	371±65	378±72	401±85
fluid administration (l)	1.8±0.5	1.9±0.6	1.8±0.4

Data are shown as mean ± SD.

Measurements

All measurements were collected with the patients in lateral position. Hemodynamic data (heart rate, systolic arterial pressure, mean arterial pressure, diastolic arterial pressure), ventilatory data (TV, peak inspiratory pressure [Ppeak], plateau inspiratory pressure [Pplateau], mean inspiratory pressure [Pmean]) were recorded, and arterial blood was analyzed using a model 865 blood gas analyzer (Chiron Diagnostics, Bayer Corp, Tarrytown, NY, USA) at the following points: (1) baseline: during two-lung ventilation before beginning of OLV; (2) OLV+20: 20 minutes after OLV; (3) OLV + 40: 40 minutes after OLV; (4) OLV + 60: 60 minutes after OLV; (5) end of surgery: 20 min after reestablishing TLV. The values of arterial blood gases were corrected for body temperature.

Statistical analysis

Data were analyzed using the SPSS 17.0 package (SPSS Inc., Chicago, IL) and were expressed as the means and standard deviations. The Kolmogorov-Smirnov test was used to analyze the distribution of quantitative variables. The primary outcome of this study was to show the changes of PaO₂ in the three groups. A power analysis with a pilot study revealed a sample size of 18 per group would be enough to provide a statistical power of 80% at a significance level of 0.05. One way ANOVA were used to compare the measurements of three groups in different study periods. Values of $P < 0.05$ were considered statistically significant.

Results

66 patients were enrolled into the study. SpO₂ of one patient in PCV group could not keep above 90% during OLV. The OLV time of one patient in the PCV-VG group was less than one

hour. These patients were excluded according to the study protocol. No significant difference was found between the three groups in the demographic characteristics and the data on the surgical procedure (Tables 1-2).

The study data of the three groups obtained during OLV were listed in Table 3. Comparison of VCV group, Ppeak was significantly lower in

PCV and PCV-VG group ($P < 0.05$), and the difference of Ppeak was not found between the PCV and PCV-VG group. There was no significant difference of the three groups in Pplateau or Pmean. PaO₂ of PCV and PCV-VG group were higher than VCV group after the point of OLV+40 ($P < 0.05$). Comparison of PCV group, PaO₂ in PCV-VG group was higher, but did not show a significantly improved during OLV ($P > 0.05$). There was no difference in arterial oxygen saturation (SaO₂), PaCO₂, Hemodynamic variables between the three groups.

Discussion

Our results showed that in a comparison of the VCV, PCV and PCV-VG modes during OLV undergoing thoracic surgery for elderly patients, the groups of PCV and PCV-VG had a significant lower in Ppeak and higher in PaO₂ than VCV group, but PCV-VG had not shown a statistically significant advantage in the results of hemodynamics, respiratory parameters, blood gas analysis compared with PCV. These results could indicate the PCV and PCV-VG had a more advantage than VCV during OLV in elderly patients.

VCV had been considered the conventional method to mechanical ventilation during OLV for a long time. But in recent years, PCV has been found renew potential due to its advantages in improving oxygenation [9-13]. These advantages might be explained through decreasing in pulmonary shunt fraction and airway pressures by the flow profile with PCV. In our precious study, the results indicated that PCV had significant advantages of intraoperative and postoperative oxygenation compared with VCV during OLV in elderly patients with poor pulmonary function [9]. Tugrul et al [10] reported that, PCV had improved arterial oxygenation during OLV in patients with a lower

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Table 3. Intraoperative variables of the patients

Variable	TLV, Preoperatively			OLV 20 min			OLV 40 min			OLV 60 min			TLV, Postoperatively		
	VCV	PCV	PCV-VG	VCV	PCV	PCV-VG	VCV	PCV	PCV-VG	VCV	PCV	PCV-VG	VCV	PCV	PCV-VG
MAP (mmHg)	83.2±11.3	84.3±9.7	85.7±10.3	78.2±12.3	77.0±14.2	79.0±12.5	80.9±12.7	81.2±9.7	82.0±11.2	84.8±10.6	82.5±11.3	84.9±11.0	83.7±14.3	85.4±13.6	82.4±14.6
HR (beats/min)	78.1±8.7	77.5±9.5	78.5±9.9	74.2±7.5	73.6±10.0	74.6±11.6	74.1±12.3	75.6±9.7	73.8±8.7	74.5±10.3	72.8±11.2	71.9±13.5	73.5±8.0	72.4±9.1	73.4±11.0
Ppeak (cmH ₂ O)	16.4±4.7	16.1±5.5	15.1±6.0	26.4±6.8*	22.9±5.6*	21.6±4.8*	28.2±6.6*	22.5±4.5*,#	21.5±4.3*,#	27.9±6.3*	21.9±4.9*,#	21.5±4.0*,#	20.4±3.8	19.2 ± 5.1	18.1 ± 5.4
Pmean (cmH ₂ O)	7.2±3.1	6.8±2.9	6.6±2.7	9.8±3.5*	8.6±2.3*	8.4±2.9*	9.1±3.9*	8.6±4.1*	8.5±3.7*	8.9±3.6*	8.8±4.0*	8.5±3.4*	7.4±3.8	7.5 ± 3.5	7.0 ± 3.2
Pplateau (cmH ₂ O)	13.2±3.9	14.5±3.5	14.2±4.1	22.3±4.4*	22.2±3.8*	21.7±4.1*	22.9±3.2*	21.5±3.9*	20.9±4.9*	23.1±4.6*	21.5±4.3*	21.2±5.0*	16.7±3.8	17.2 ± 4.4	16.9 ± 4.0
PaO ₂ (mmHg)	341±78	334±72	338±85	165±39*	181±43*	182±51*	158±49*	197±55*,#	205±42*,#	161±56*	198±56*,#	208±46*,#	318±69	325 ± 80	320 ± 71
PaCO ₂ (mmHg)	34.7±7.1	35.9±6.8	35.9±6.1	37.6±5.6	37.4±5.2	36.1±5.2	37.9±6.1	36.9±5.9	35.9±6.2	38.0±5.4	36.9±6.9	37.1 ±6.0	34.4±5.5	33.9 ±5.9	34.3 ±6.2
SaO ₂ (%)	99.7±0.4	99.6±0.6	99.5±0.4	97.2±3.1	97.6± 3.7	98.4±2.4	98.1±2.3	98.5±2.4	98.9±1.9	98.7±2.0	98.4±2.9	98.5±2.0	99.0±0.9	98.9 ±1.2	99.2 ±1.0

Data are shown as mean ± SD. OLV=One-lung ventilation; TLV=Two-lung ventilation; PaCO₂=arterial carbon dioxide tension; PaO₂=arterial oxygen tension; PCV=Pressure controlled ventilation; VCV=Volume controlled ventilation; PCV-VG=Pressure controlled ventilation volume guaranteed; Pmean=mean inspiratory pressure; Ppeak=peak inspiratory pressure; Pplateau=plateau inspiratory pressure; SaO₂=arterial oxygen saturation; *P<0.05 (baseline v others periods); #P<0.05 (VCV v PCV, PCV-VG).

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forced vital capacity. Senturk et al [11] showed that PCV with 4 cm H₂O PEEP could improve the arterial oxygenation compared to VCV with zero PEEP. At the same time, some researches presented a different view that PCV had no advantage over VCV during OLV [14, 15].

PCV-VG is the newest ventilation mode in anesthesia machine. It delivers the preset tidal volume with the lowest possible pressure. PCV-VG breaths are characterized by a decelerating flow waveform and square pressure waveform. PCV-VG mode will deliver breaths with the efficiency and clinical benefits of PCV, yet still compensate for changes of compliance with consistent tidal volumes. Because of its benefits, some scholars had reported its clinical applications during surgery. Jun et al [17] showed that PCV-VG mode might have better effects by decreasing inspiratory pressure parameters and improving arterial oxygenation than VCV in patients undergoing thoracic surgery with a controlled, crossover design. In contrast, Seok et al [18] reported that PCV-VG did not provide significantly improved arterial oxygen tension, but significantly attenuated airway pressure compared with VCV during OLV in patients with normal lung function. Joanna et al [19] showed that PCV-VG and PCV were superior to VCV ventilation in their ability to provide ventilation with the lowest PIP in adolescents and young adults undergoing laparoscopic bariatric surgery, but there was no difference in oxygenation (PaO₂), ventilation (PaCO₂) or hemodynamic variables between the three ventilation modes.

In our results, PCV-VG and PCV had the significant advantages compared with VCV. We think one of the reasons was that we had chosen the elderly patients into our study. The lung tissues changes, muscle performance diminishes and the chest wall becomes stiffer with age can reduce the alveolar surface tension and increase the residual volume [5]. These changes impact on the static and dynamic lung function. Vital capacity (VC) and Forced expiratory volume in 1 s (FEV-1) drop progressively with age also [6]. Because of the decreasing of respiratory function and the degeneration of respiratory system, elderly people have potentially the risk of developing hypoxemia, even the risk of developing perioperative lung injury and pulmonary complications [7]. VCV uses a constant inspired flow that has been gained as the

tidal volume delivered through producing a progressive increase of airway pressure to the peak inspiratory pressure. PCV and PCV-VG mode perform appropriate flow to maintain the set inspiratory pressure, which can improve the static and dynamic lung compliance and reduce the degree of barotrauma during mechanical ventilation. These advantages of PCV and PCV-VG mode might alleviate ventilation/perfusion imbalances, improve the homogeneous distribution of inspired gas, reduce the shunting of blood between lungs, gain better oxygenation and decrease the risk of lung injury, especially suitable for elderly patients.

Although PCV-VG ventilation mode has more advantages than PCV mode, the results of our study found no difference between the two ventilation modes. We think the reason is that the depth of anesthesia, muscle relaxation and surgical manipulations have been controlled stably, and the substantially alter of compliance and lung resistance have been avoided as much as possible. In addition, the patient's lung function was not poor and the changes of lung compliance was not serious according to the preoperative examination in spite of the patient's age above 65 in our study. Therefore PCV-VG have no chance to perform its advantages which can accommodate the changes of compliance and resistance automatically. But our clinical experience has indicated that PCV-VG is more suitable to manage in the process of mechanical ventilation because of its advantages. Therefore, PCV-VG ventilation mode is the primary choice in our hospital during OLV undergoing thoracic surgery.

A limitation of this study was that and the generalizability of the conclusions was limited because a small group of patients was selected in a single-center. In addition, surgical manipulation made by the different type and scope of surgical resection may potentially produce some effects on the results of our study.

Conclusions

In conclusion, Compared with VCV, the use of PCV and PCV-VG have a significant advantage in intraoperative oxygenation and airway pressure for elderly patients undergoing OLV. Our study found no difference between PCV and PCV-VG ventilatory modes.

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Disclosure of conflict of interest

None.

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