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Assessment of intraoperative oxygenation function and trauma degree of PCV−VG and VCV mode for elderly patients with laparoscopic abdominal surgery

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ABSTRACT

Objective: To study the intraoperative oxygenation function and trauma degree of pressure-controlled ventilation-volume guaranteed (PCV-VG) and volume-controlled ventilation (VCV) mode for elderly patients with laparoscopic abdominal surgery. **Methods:** 60 elderly patients with laparoscopic abdominal surgery were selected for study and randomly divided into two groups (n=30), group A received ventilation in accordance with sequential VCV-PCV-VG mode, group B received ventilation in accordance with the sequential PCV-VG-VCV mode, and the respiratory function parameters and arterial blood gas parameters and serum damage indexes were determined before the start of pneumoperitoneum (T0), 1 h after the start of the first ventilation mode after the start of pneumoperitoneum (T1), 1 h after the switch of ventilation mode (T2) and after the end of pneumoperitoneum (T3). **Results:** At T1, P_{peak}, mean airway pressure (P_{mean}) and plateau airway pressure (P_{plant}) of group A were significantly higher than those of group B (P<0.05), partial pressure of oxygen (PaO_2) was significantly lower than that of group B (P<0.05), and pulse oxygen saturation (SpO_2) and partial pressure of carbon dioxide ($PaCO_2$) were not significantly different from those of group B; at T2 and T3, P_{peak}, P_{mean} and P_{plant} of group A were significantly lower than those of group B (P<0.05), PaO_2 were significantly lower than those of group B (P<0.05), and SpO_2 and $PaCO_2$ were not significantly different from those of group B. At T1, serum soluble receptor for advanced glycation end-product (sRAGE), KL-6 (krebs. von den Iungen-6), tumor necrosis factor-α (TNF-α) and malondialdehyde (MDA) content of group A were significantly higher than those of group B (P<0.05); at T3, serum sRAGE, KL-6, TNF-α and MDA content of group A were significantly lower than those of group B (P<0.05). **Conclusions:** PCV-VG mode for elderly patients with laparoscopic abdominal surgery can reduce airway pressure, improve lung compliance and alveolar oxidation, and reduce lung injury and systemic trauma.

1. Introduction

Laparoscopic abdominal surgery is a common minimally invasive surgery for general surgical treatment of gastrointestinal diseases, it causes significantly less surgical trauma than open surgery, and it is more suitable for the elderly patients with various bodily function degradation. However, laparoscopic surgery process requires the establishment of pneumoperitoneum, increased intra-abdominal pressure can elevate the diaphragm and affect cardiopulmonary function, and the postoperative pulmonary complications, acute lung injury (ALI), in particular, is the important cause of death in elderly patients after surgery. Thus choosing the reasonable intraoperative ventilation mode helps to ensure the normal pulmonary ventilation volume and oxygenation.

Volume-controlled ventilation (VCV) is currently the most widely used ventilation mode in general anesthesia[1], but a constant velocity may result in higher peak inspiratory pressure and increase the incidence of barotrauma, and easily leads to uneven distribution of gas in the lung. Pressure-controlled ventilation mode (PCV) is

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with lower airway pressure than VCV, but the ventilation volume is greatly influenced by lung compliance and insufficient ventilation easily occurs during operation[2,3]. Pressure-controlled ventilation-volume guaranteed (PCV-VG) is a new ventilation mode in general anesthesia developed in recent years, which provides decelerating flow through constant pressure, can be adjusted automatically according to the mechanical parameters of patients' each breath, uses the smallest positive pressure to provide the scheduled tidal volume, and combines the advantages of both VCV and PCV[4,5]. But at present, there iws less clinical study about the PCV-VG ventilation mode in elderly patients, and randomized controlled trials of cross-over design were to be adopted in the study to compare the influence of the PCV-VG and VCV mode for elderly patients with laparoscopic abdominal surgery on intraoperative oxygenation function and degree of trauma.

2. Materials and methods

2.1. Research subjects

60 elderly patients who received laparoscopic gastric cancer and colorectal cancer surgery in our hospital between June 2012 and December 2015 were selected as the research subjects, and all patients were > 70 years old and with ASA II–III grade; all patients received laparoscopic surgery performed by the same group of doctors and were with intraoperative breath control for more than 2 h, and patients with severe cardiopulmonary dysfunction and chronic airway disease were excluded. After informed consent was obtained, and random number table was used to divide the included patients into group A and group B (n=30) who received different ventilation modes. Group A: received sequential VCV-PCV-VG ventilation mode, included 18 male cases and 12 female cases, were (75.6±6.3) years old, were with BMI (21.5±3.5) kg/m^2, and included 19 cases with ASA II grade and 11 cases with III grade; group B: received sequential PCV-VG-VCV ventilation mode, included 19 male cases and 11 female cases, were (74.9±6.8) years old, were with BMI (21.9±3.4) kg/m^2, and included 17 cases with ASA II grade and 13 cases with III grade. The two groups of patients were not significantly different in general information (P>0.05).

2.2. Anesthesia methods

30 min before anesthesia, patients received intramuscular injection of atropine 0.5 mg and luminal 0.1 g. After they entered the OR, noninvasive blood pressure (BP), heart rate (HR), electrocardiogram (ECG), pulse oxygen saturation (SpO_2) and end-tidal carbon dioxide concentration ($P_{ET}CO_2$) were monitored. Fluid pathway was established, radial arterial puncture intubation was conducted under local anesthesia to monitor invasive arterial blood pressure, and blood gas analysis was conducted. Patients received midazolam 0.05 mg/kg, propofol 2 mg/kg, fentanyl 2 μg/kg and Cisatracurium besilate 0.5 mg/kg for general anesthesia induction, and after induction, patients received tracheal intubation and were connected to Datex-Ohmeda (Advance-Aisys) anesthesia machine. Target-controlled propofol and remifentanil infusion were applied during operation for maintenance, targeted plasma concentrations were 2.5–3.0 μg/mL and 4–6 ng/mL, and intraoperative BIS was maintained between 40 and 60. And fentanyl and Cisatracurium besilate were discontinuously added as needed. Vasodilators and inhalation anesthetics were not used during operation.

Group A received sequential VCV-PCV-VG ventilation mode, VCV mode of ventilation was used for 1 h after surgical pneumoperitoneum started, and then PCV mode was used for 10 min of elution and switched to PCV-VG mode until the end of operation; Group B received sequential PCV-VG-VCV ventilation mode: PCV-VG mode of ventilation was used for 1 h after surgical pneumoperitoneum started, and then PCV mode was used for 10 min of elution and switched to VCV mode until the end of operation. Specific parameters were as follows: FiO_2 was 0.6, V_T was 6–8 mL/kg, respiratory frequency was 12–16 times/min, maintenance $P_{et}CO_2$ was 35–40 mmHg and PEEP was 5 mmHg.

2.3. Observation indexes

2.3.1. Respiratory function parameters

Before the start of pneumoperitoneum (T0), 1 h after the start of the first ventilation mode after the start of pneumoperitoneum (T1), 1 h after the switch of ventilation mode (T2) and after the end of pneumoperitoneum (T3), the following respiratory function parameters were read from the anesthesia machine: mean airway pressure (P_{mean}), plateau airway pressure (P_{plant}) and blood oxygen saturation (SpO_2); and arterial blood was collected to determine the partial pressure of carbon dioxide ($PaCO_2$) and partial pressure of oxygen (PaO_2).

2.3.2. Trauma degree assessment

At T1 and T3, peripheral venous blood was collected from two groups of patients respectively and centrifuged to get serum, and enzyme-linked immunosorbent assay kit was used to determine serum soluble receptor for advanced glycation end-product (sRAGE), KL-6 (krebs. von den Iungen-6), tumor necrosis factor-α (TNF-α) and malondialdehyde (MDA) content.

2.4. Statistical analysis

SPSS20.0 software was used to input and analyze data and all data was in terms of $\bar{x}\pm s$. Measurement data analysis between

two ventilation modes in cross-over stage was by *t* test, pair-wise comparison of data in different points in time was by variance analysis of repeated measures and $P < 0.05$ indicated statistical significance in differences.

3. Results

3.1. Respiratory function parameters

At T0, P_{peak}, P_{mean} and P_{plant} of group A were higher than those of group B (P<0.05); at T1, P_{peak}, P_{mean} and P_{plant} of group A were higher than those of group B (P<0.05); at T2 and T3, P_{peak}, P_{mean} and P_{plant} of group A were significantly lower than those of group B (P<0.05). At T0, P_{peak}, P_{mean} and P_{plant} of group A were significantly higher than those of same group at T3 (P<0.05), and P_{peak}, P_{mean} and P_{plant} of group B were significantly lower than those of same group at T3 (P<0.05). At T1, P_{peak}, P_{mean} and P_{plant} of group A were significantly higher than those of same group at T2 (P<0.05), P_{peak}, P_{mean} and P_{plant} of group B were significantly lower than those of same group at T2 (P<0.05), and respiratory function parameters P_{peak}, P_{mean} and P_{plant} were significantly different between two group at T1–T2 (P<0.05) (Table 1).

3.2. Arterial blood gas parameters

At T0, arterial blood gas parameters SaO_2, PaO_2 and $PaCO_2$ were not significantly different between two groups (P>0.05). At T1, PaO_2 of group A was lower than that of group B (P<0.05) while SpO_2 and $PaCO_2$ were not significantly different from those of group B (P>0.05); at T2 and T3, PaO_2 of group A were significantly higher than those of group B (P<0.05) while SpO_2 and $PaCO_2$ were not significantly different from those of group B (P>0.05). PaO_2 were significantly different between two groups at T1-T3 (P<0.05) (Table 2).

3.3. Serum lung injury indexes and systemic trauma indexes

Comparison of serum lung injury indexes and systemic trauma indexes between two groups at T1 and T3 is shown in Table 3:

Table 1

Comparison of airway pressure parameters between two groups at T0-T3 (n=30, $\bar{x}\pm s$).

Groups	Time point	P_{peak} (cm H_2O)	P_{mean} (cm H_2O)	P_{plant} (cm H_2O)
Group A	T0	18.10±3.90	7.50±0.45	15.80±2.10
	T1	30.70±3.78*	11.31±0.93*	26.74±3.26*
	T2	25.10±3.82*△	10.42±0.88*△	24.13±3.88*△
	T3	14.94±1.83*#	7.02±0.91*#	13.09±1.77*#
Group B	T0	13.09±1.67	6.87±0.96	12.02±1.84
	T1	24.14±2.34	10.72±3.50	23.13±2.22
	T2	29.53±1.88△	11.78±1.02△	2 6.42±3.65△
	T3	19.03±2.42#	7.63±1.14#	16.14±2.52#

*P<0.05 vs group B at the same time point. #P<0.05 vs T0 in the same group. △P<0.05 vs T1 in the same group.

Table 2

Comparison of arterial blood gas parameters between two groups at T0-T3 (n=30, $\bar{x}\pm s$).

Groups	Time point	SaO_2 (%)	$PaCO_2$ (mmHg)	PaO_2 (mmHg)
Group A	T0	99.32±0.72	33.59±4.85	181.14±18.24
	T1	97.79±1.72	33.52±4.03	135.22±18.87*
	T2	98.14±0.64	35.74±2.02	152.32±19.25*
	T3	98.30±1.30	34.52±4.52	174.42±17.85*
Group B	T0	99.48±0.66	34.02±5.13	189.64±20.24
	T1	98.10±1.75	32.97±3.46	150.15±18.67
	T2	97.67±1.03	35.02±2.95	139.34±18.26
	T3	99.56±0.41	34.49±4.53	181.03±17.93

*P<0.05 vs group B at the same time point.

Table 3

Comparison of serum lung injury indexes and systemic trauma indexes at T1 and T3 (n=30, $\bar{x}\pm s$).

Groups	T1				T2			
	sRAGE (μg/L)	KL-6 (kU/L)	TNF-α (ng/L)	MDA (μmol/L)	sRAGE (μg/L)	KL-6 (kU/L)	TNF-α (ng/L)	MDA (μmol/L)
Group A	1.42±0.19	786.76±91.45	28.76±5.24	6.19±0.86	1.15±0.13	586.33±65.28	21.28±3.35	4.92±0.56
Group B	0.93±0.11	445.65±62.56	17.25±2.85	4.54±0.64	1.77±0.23	809.13±94.35	34.68±5.24	7.52±0.91
t	6.843	8.018	7.484	7.008	6.782	7.484	7.293	7.038
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

serum sRAGE, KL-6, TNF-α and MDA content of group A were significantly higher than those of group B (P<0.05); serum sRAGE, KL-6, TNF-α and MDA content of group A were significantly lower than those of group B (P<0.05). Serum sRAGE, KL-6, TNF-α and MDA content were significantly different between two groups at T1 and T3 (P<0.05).

4. Discussion

Various bodily functions, especially cardiopulmonary function of elderly patients significantly degrade, the risk of anesthesia is bigger, and the requirement for anesthesia is also higher. Laparoscopic surgery is a normal minimally invasive way of general surgery, and intraoperative pneumoperitoneum establishment could elevate the diaphragm and oppress the heart and lungs, thus influencing intraoperative pulmonary ventilation and oxygenation function. When elderly patients receive laparoscopic surgery, choosing reasonable ventilation mode can ensure normal pulmonary ventilation and oxygenation function[6]. VCV and PCV are two clinical common ventilation modes. In the process of VCV ventilation, positive airway pressure can ensure adequate ventilation volume, but excessive airway pressure will lead to alveolar over-expansion and cause alveolar damage, and alveolar volume damage is also considered as a common complication of VCV ventilation mode[7,8]. The cardiopulmonary function of elderly patients is poor, the elevated diaphragm during laparoscopic surgery can also cause extrusion to the lungs, larger minute ventilation is needed because of the CO_2 absorption into the bloodstream, and conducting VCV mode of ventilation at this time will cause pulmonary barotraumas and then influence alveolar oxygenation function because of excessive airway ventilation and airway pressure.

PCV-VG is a ventilation mode newly developed in recent years, and the ventilation mode combines the advantages of VCV and PCV ventilation mode[9], sets patients' tidal volume and minute ventilation before ventilation, provides decelerating flow through constant pressure during ventilation, and automatically adjusts the airway pressure and ventilation volume according to patients' lung compliance to achieve the most ideal alveolar ventilation, which not only reduces the airway and alveolar damage caused by high airway pressure, but also ensures the effective alveolar ventilation and gas exchange[10,11]. In order to define the airway pressure and lung compliance of PCV-VG and VCV ventilation modes, the sequential PCV-VG-VCV ventilation and sequential VCV-PCV-VG ventilation were conducted respectively in the study, and comparison of airway pressure and pulmonary compliance between two ventilation modes showed that at T1, group B who adopted PCV-VG mode were with lower P_{peak}, P_{mean} and P_{plant}; at T2 and T3, group A who adopted PCV-VG mode were with lower P_{peak}, P_{mean} and P_{plant}. This means that PCV-VG ventilation mode can reduce airway pressure and decrease barotrauma.

Decreased airway pressure under PCV-VG ventilation mode is because that the ventilation mode provides decelerating flow through constant pressure, adjusts the mechanical parameters of every breath according to the patients' lung compliance, uses the smallest positive pressure to provide scheduled tidal volume, and reduces airway pressure on the premise of guaranteeing ventilation volume; so to some extent, it will make for the alveolar ventilation and oxygenation[12], and reduce the damage caused by excessive airway pressure. In the study, intraoperative arterial blood gas parameters of two groups of patients were analyzed in order to reflect the alveolar ventilation and oxygenation state, and the result showed that at T1, group B who adopted PCV-VG mode were with higher arterial partial pressure of oxygen; at T2 and T3, group A who adopted PCV-VG mode were with higher arterial partial pressure of oxygen. This means that the PCV-VG ventilation mode is with matched ventilation volume and lung compliance, guarantees minute ventilation, and also reduces the airway pressure and decreases alveolar damage, and meantime, the decelerating flow provided by PCV-VG mode is superior to VCV mode in the alveolar ventilation and gas distribution[13], so it has improving effect on the alveolar oxygenation function and patients' intraoperative arterial partial pressure of oxygen increases.

Excessive ventilation will cause lung tissue damage and increase the trauma caused by systemic inflammatory response and oxidative stress. sRAGE and KL-6 are expressed on the type I and type II alveolar surface respectively, excessive ventilation will cause alveolar over-expansion as well as fracture and damage, and the sRAGE and KL-6 on the alveolar surface are released into the blood circulation[14,15]. In the study, analysis of the alveolar damage molecules in serum confirmed that at T1, group B who adopted PCV-VG mode were with lower serum sRAGE and KL-6 content; at T3, group A who adopted PCV-VG mode were with lower serum sRAGE and KL-6 content. This means that PCV-VG ventilation mode can reduce alveolar damage. Inflammatory injury and oxidative stress injury caused by operation and excessive ventilation are the important mechanisms of the alveolar damage, TNF-α is a pro-inflammatory factor mediating inflammatory response, MDA is the product of oxidative stress, and both can reflect the degree of inflammatory response and oxidative stress in the body[16–18]. In the study, analysis of TNF-α and MDA content in serum proved that at T1, group B who adopted PCV-VG mode were with lower serum TNF-α and MDA content; at T3, group A who adopted PCV-VG mode were with lower serum TNF-α and MDA content.

To sum up, the study results show that in the ventilation process of laparoscopic abdominal surgery in elderly patients, PCV-VG ventilation mode can optimize the respiratory mechanical parameters and reduce airway pressure, it helps to improve patients' oxygenation

and reduce lung injury, but the effect of the ventilation mode on patients' prognosis still requires further study.

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