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Intraoperative and postoperative evaluation of low tidal volume combined with low-level positive end-expiratory pressure ventilation in laparoscopic surgery in elderly patients

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ABSTRACT

Objective: To evaluate intraoperative and postoperative condition of low tidal volume combined with low-level positive end-expiratory pressure ventilation in laparoscopic surgery in elderly patients. **Methods:** A total of 176 cases of elderly patients (more than 60 years old) receiving laparoscopic surgery in our hospital from July 2013 to July 2015 were selected as research subjects and randomly divided into observation group and control group, each group included 88 cases, control group received conventional ventilation strategy, observation group received low tidal volume combined with low-level positive end-expiratory pressure ventilation strategy, and then levels of hemodynamic indexes, respiratory mechanical indexes, serology indexes and cerebral vessel related indexes, etc of two groups were compared. **Results:** Intraoperative and postoperative heart rate and mean arterial pressure levels of observation group were lower than those of control group, arterial partial pressure of oxygen and oxygenation index levels were higher than those of control group and differences had statistical significance (P<0.05); intraoperative APIP and Pplat values of observation group were lower than those of control group, Cs value was higher than that of control group and differences had statistical significance (P<0.05); intraoperative and postoperative serum IL-8 and TNF-α levels of observation group were lower than those of control group, IL-10 level was higher than that of control group and differences had statistical significance (P<0.05); intraoperative and postoperative $PjvO_2$, $SjvO_2$ and $CjvO_2$ levels of observation group were higher than those of control group, $Da\text{-}jvO_2$ level was lower than that of control group and differences had statistical significance (P<0.05). **Conclusions:** When elderly patients receive laparoscopic surgery, the use of low tidal volume combined with low-level positive end-expiratory pressure ventilation strategy can stabilize hemodynamic level and respiratory function as well as reduce systemic inflammatory state and the effect on cerebral blood supply in patients.

1. Introduction

Laparoscopic surgery in the elderly is one of the high factors of postoperative pulmonary complication, intraoperative artificial pneumoperitoneum pressure, head-down position and CO_2 absorbance into the blood, *etc* all cause decreased pulmonary compliance, increased airway pressure and reduced functional residual volume in mechanical ventilation, and it is an important clinical topic to select an suitable ventilation mode to protect patients' lungs and other vital organs[1]. Currently accepted traditional ventilation method of large tidal volume and high Ppeak may cause the potential risk of lung damage and also have a certain influence on the prognosis. Studies have shown that in patients with acute lung injury, low tidal volume ventilation mode can reduce mortality[2-3]. The research added positive end-expiratory pressure (PEEP) to low tidal volume mode and focused on the effect of ventilation strategies on indexes of various systems in perioperative period of elderly laparoscopic patients, hereby reporting as follows:

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2. Information and methods

2.1. General information

A total of 176 cases of elderly patients (more than 60 years old) receiving laparoscopic surgery in our hospital from July 2013 to July 2015 were selected as research subjects and graded into II–III grades according to grading of American Society of Anesthesiologists (ASA), estimated operation time was more than 2 h and duration of ventilation was more than 3 h. All patients were with no history of chronic diseases of the respiratory system, alcoholism or drug abuse, or mental illness.

The 176 patients were randomly divided into observation group and control group, each group included 88 cases, control group included 49 male cases and 39 female cases who were 62–71 years old with average age of (67.33±2.81) years, and the body weight was 48–73 kg with average of (58.71±4.86) kg; observation group included 48 male cases and 40 female cases who were 63–70 years old with average age of (66.45±3.02) years, and the body weight was 47-72 kg with average of (55.79±4.73) kg. The research was approved by the hospital ethics committee, patients and families signed informed consent, differences in baseline information between groups had no statistical significance, and they were comparable.

2.2. Anesthetic methods and ventilation strategies

2.2.1. Anesthetic methods.

Both groups received general anesthesia with endotracheal intubation as follows: after patients entered OR, upper extremity venous access was established, balanced solution was connected, and instruments monitoring vital signs such as electrocardiogram, invasive blood pressure, oxygen saturation and bispectral index, etc were connected. After 3 L/min and 100% oxygen mask denitrogenation and preoxygenation, 0.05 mg/kg of midazolam, 5 μg/kg of fentanyl, 0.2 mg/kg of cisatracurium and 2.5 mg/kg of propofol were given for anesthesia induction. Reinforced endotracheal tube was placed and then fixed in the appropriate calibration, Drager anesthesia machine was connected and mechanical ventilation was carried out.

2.2.2. Mechanical ventilation strategies.

Observation group received low tidal volume combined with low-level positive end-expiratory pressure ventilation as follows: setting tidal volume to 7 mL/kg and PEEP 5 cm H_2O; control group received conventional ventilation strategy as follows: tidal volume 12 mL/kg and PEEP 0 cm H_2O.

Ventilation frequency of both groups was 12 times/min, tidal volume was kept unchanged and ventilation frequency was adjusted to maintain $PETCO_2$ at 35–45mm Hg.

2.3. Observation indexes

2.3.1. Hemodynamic indexes.

Before anesthesia induction (T1), ventilation for 60 min (T2) and 15min after extubation (T3), the changes of intraoperative heart rate (HR), mean arterial pressure (MAP), Arterial Partial Pressure of Oxygen (PaO_2) and oxygenation index (PsO_2/FiO_2) values were observed.

2.3.2. Respiratory mechanical indexes.

Airway peak inspiratory pressure (APIP), plateau pressure (Pplat) and CSt static compliance (Cs) in patients under mechanical ventilation mode were observed.

2.3.3. Serology indexes.

1 h after mechanical ventilation and 1 h after surgery, 3 mL of fasting peripheral venous blood of patients was collected, placed in test tubes and centrifuged at 3 000 r/min, upper serum was collected, stored in the freezer at -80 °C and set aside. Enzyme-linked immunosorbent assay (ELISA) was used to detect interleukin-8 (IL-8), interleukin-10 (IL-10) and tumor necrosis factor-α (TNF-α) in it.

2.3.4. Cerebral vessel related indexes.

Radial arterial blood was collected, Partial Pressure of jugular vein ($PjvO_2$) and oxygen saturation of jugular vein ($SjvO_2$) were detected and Fick formula was used to calculate oxygen contents of cerebral artery and jugular vein, including oxygen content of jugular vein ($CjvO_2$)=1.39 Hb $SjvO_2$+0.003 $PjvO_2$; arterial oxygen content (CaO_2)=1.39 Hb SaO_2+0.003 PaO_2; arterio-venous oxygen difference ($Da\text{-}jvO_2$) = CaO_2-$CjvO_2$.

2.4. Statistical methods

Data obtained in the research was statistically analyzed by SPSS21.0 software, measurement data was by t test, counting data was by chi-square test and P<0.05 was the standard of statistical significance in differences.

3. Results

3.1. Hemodynamic indexes

Observation group received low tidal volume combined with low-level positive end-expiratory pressure ventilation strategy, differences in preoperative heart rate, mean arterial pressure, arterial partial pressure of oxygen and oxygenation index levels had no statistical significance, intraoperative and postoperative heart rate and mean arterial pressure levels of observation group were lower than those of control group, arterial partial pressure of oxygen and oxygenation index levels were higher than those of control group and differences had statistical significance ($P<0.05$), shown in Figure 1.

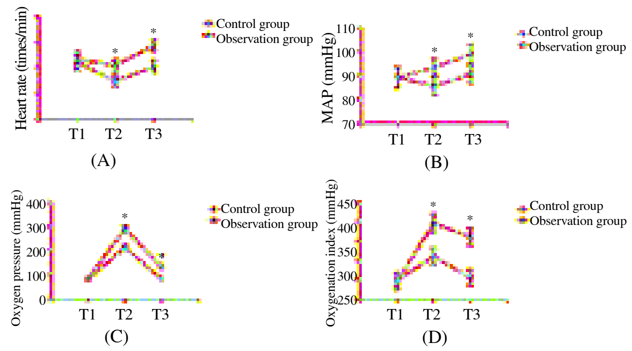

Figure 1. Comparison of perioperative hemodynamic index values between two groups.

3.2. Respiratory mechanical indexes

After observation group received low tidal volume combined with low-level positive end-expiratory pressure ventilation strategy, related respiratory mechanical index levels were detected during surgery, and results were as follows: intraoperative APIP and Pplat values of observation group were lower than those of control group, Cs value was higher than that of control group and differences had statistical significance ($P<0.05$), shown in Figure 2.

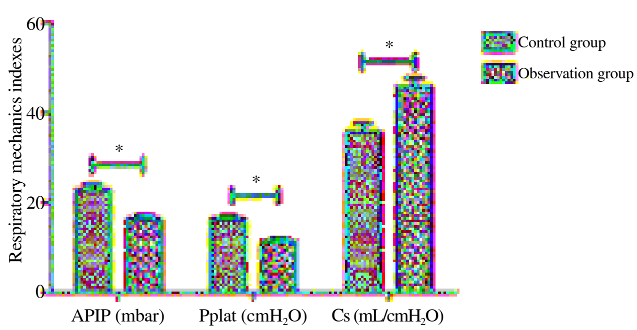

Figure 2. Comparison of intraoperative respiratory mechanical index values between two groups.

3.3. Serology indexes

Observation group received low tidal volume combined with low-level positive end-expiratory pressure ventilation, ELISA was used to detect serum inflammatory factor levels, and results were as follows: intraoperative and postoperative serum IL-8 and TNF-α levels were lower than those of control group, IL-10 level was higher than that of control group and differences had statistical significance ($P<0.05$), shown in Table 1.

3.4. Cerebral vessel related indexes

Observation group received low tidal volume combined with low-level positive end-expiratory pressure ventilation, intraoperative and postoperative radial arterial blood was drawn to detect cerebral vessel related index levels, and results were as follows: intraoperative and postoperative $PjvO_2$, $SjvO_2$ and $CjvO_2$ levels of observation group were higher than those of control group, Da-jvO_2 level was lower than that of control group and differences had statistical significance ($P<0.05$) , shown in Table 2.

4. Discussion

Pneumoperitoneum during laparoscopic surgery may have significant effect on mechanical ventilation process of patients, elderly patients, in particular, have poor reserve of heart, lung and other organs, and high pneumoperitoneum pressure can lead to severe hemodynamic fluctuation and respiratory dysfunction, causing dysfunction of multiple organs in patients after surgery. Ventilation strategy in laparoscopic surgery has been the focus of clinical debate, and the ultimate goal of intraoperative mechanical

Table 1

Comparison of intraoperative and postoperative serology index values between two groups (pg/mL).

Groups	IL-8		IL-10		TNF-α	
	Intraoperative	Postoperative	Intraoperative	Postoperative	Intraoperative	Postoperative
Observation group	30.82±2.76	35.11±3.47	30.82±2.71	35.76±3.44	47.28±3.91	58.62±6.01
Control group	37.89±3.42	47.82±4.06	23.67±2.45	26.81±2.76	58.71±4.27	73.72±7.25
t	5.835	7.182	7.527	8.093	6.872	9.173
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Table 2

Comparison of intraoperative and postoperative cerebral vessel related index levels between two groups (pg/mL).

Groups	$PjvO_2$ (mmHg)		$SjvO_2$ (%)		$CjvO_2$ (%)		Da-jvO_2 (%)	
	Intraoperative	Postoperative	Intraoperative	Postoperative	Intraoperative	Postoperative	Intraoperative	Postoperative
Observation group	59.17±4.88	65.83±5.97	85.11±6.34	86.33±6.79	14.36±1.76	15.17±1.84	2.31±0.37	2.34±0.31
Control group	54.34±4.32	60.27±5.69	79.76±6.11	81.24±6.05	12.28±1.31	12.53±1.43	3.76±0.42	3.68±0.41
t	6.283	7.128	6.726	7.284	5.232	7.927	6.823	7.192
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

ventilation parameter settings is to protect patients' lung function and reduce the negative effect of pneumoperitoneum on patients' systemic state[4-5]. Protective pulmonary ventilation is a new mechanical ventilation strategy developed in recent years, low tidal volume (6-8 mL/kg) and permissive hypercapnia were adopted and low-level positive end-expiratory pressure (PEEP) was added in order to ease the harm of intraperitoneal CO_2 pressure to patients through changes of this series of parameters.

Both laparoscopic surgery and mechanical ventilation can enhance patients' perioperative systemic stress response, vascular elasticity in the elderly reduces and it is hard to maintain hemodynamic homeostasis, establishment of laparoscopic pneumoperitoneum causes lifted diaphragm, increased resistance of heart pump and accelerated heart rate, patients may have some degree of hemodynamic instability, and patients accompanied by basic coronary heart disease can even have heart failure because of excessive increase in heart rate[6]. Mechanical ventilation may further aggravate the cycle instability in elderly patients, studies have shown that in conventional large tidal volume ventilation mode, probability of intraoperative hypotension in the elderly increases significantly, and it is thus clear that laparoscope and large tidal volume ventilation can have a tremendous impact on cyclostationarity in elderly patients[7]. In the research, observation group received low tidal volume combined with low-level PEPP protective ventilation strategy in laparoscopic surgery, and results showed that intraoperative and postoperative heart rate and mean arterial pressure levels of observation group were lower, and arterial partial pressure of oxygen and oxygenation index levels were higher, indicating that low tidal volume could reduce the resistance brought to patients' heart pump by establishing pneumoperitoneum and ensure a certain degree of same total pressure; low-level PEPP can prevent alveolar collapse and recruitment difficulty, ensure effective alveolar gas exchange and oxygenation as well as maintain normal partial pressure of oxygen[8].

Studies have shown that with the prolongation of ventilation, conventional large tidal volume ventilation-induced functional lung injury may cause pulmonary edema over time, increase airway resistance and decrease pulmonary gas exchange capacity, manifested as reduced oxygenation index of lung in data[9]. Mechanical ventilation can inactivate pulmonary surfactant and significantly decrease pulmonary compliance, and in addition, respiratory function in the elderly decreases, quality of alveolar elastin changes and pulmonary elastic recoil progressively declines, prone to decreased pulmonary compliance and atelectasis caused by alveolar collapse in general anesthesia laparoscopy[10]. In the research, observation group received low tidal volume combined with low-level PEPP, reducing tidal volume per minute while giving certain positive end-expiratory pressure, which could prevent complete alveolar collapse, contribute to the re-expansion of the collapsed alveoli and effectively increase static lung compliance as well as effective alveolar gas exchange. Above results showed that intraoperative APIP and Pplat values of observation group were lower, Cs value was higher and it indicated that protective lung ventilation strategy could effectively avoid lung injury brought by large tidal volume, reduce airway resistance while increase alveolar oxygenation function, showing that the low-level PEPP settings could promote pulmonary surfactant generation and activity, improve static lung compliance and truly exert the lung-protective effect.

In laparoscopic surgery, CO_2 pneumoperitoneum-induced abdominal pressure increase and hypercapnia, etc can all further add to intraoperative stress response, and during mechanical ventilation, large tidal volume-induced alveolar overdistention and repeated opening can both promote inflammation. Studies have shown that there is generally some degree of systemic inflammatory state in patients after laparoscopic surgery, which is, apart from surgical trauma stress-related, also related to the establishment of laparoscopic pneumoperitoneum[11]. In the research, intraoperative and postoperative inflammatory state of two groups was compared, and results showed that intraoperative and postoperative IL-8 and TNF-α levels of observation group were lower and IL-10 level was higher. Both IL-8 and TNF-α can cause large raise of neutrophils and macrophages in the lung, generate a lot of elastase and collagenase as well as release a lot of active oxygen after activation, directly damage alveolar surface epithelial and vascular endothelial cells and induce lung tissue injury. IL-10 is an important anti-inflammatory factor in the body and can inhibit the pro-inflammatory effect of mononuclear macrophages, reduce the infiltration of neutrophils and other inflammatory factors in the lung and inhibit the generation of related pro-inflammatory factor[12,13]. When patients are in inflammatory state, IL-10 level may increase dramatically, promoting body's inflammation/anti-inflammation balance restoration and avoiding body's immunosuppression caused by excessive inflammatory response. Above results showed that protective lung ventilation strategy could reduce systemic inflammatory state in patients, which was related to both decrease of pro-inflammatory factors and enhancement of anti-inflammatory ability.

It is known that anesthetics such as propofol can directly reduce cerebral blood flow, current debate about laparoscopic surgery on brain function of elderly patients is more and studies have shown that the incidence of postoperative cognitive dysfunction in laparoscopic patients is higher. In the research, values of intraoperative and postoperative cerebral blood flow related indexes were detected, and results showed that intraoperative and postoperative $PjvO_2$, $SjvO_2$ and $CjvO_2$ levels of observation group were higher and Da-jvO_2 level was lower. Vast majority of glomus jugular blood is from cerebral venous reflux, $SjvO_2$ and $CjvO_2$ can reflect the cerebral oxygen delivery and consumption balance between cerebral metabolic rate of oxygen and cerebral blood flow, and increase of their levels indicates there is spare cerebral oxygen delivery relative to cerebral oxygen consumption[14,15]. Da-jvO_2 is believed as the gold standard for assessment of cerebral oxygen consumption and decrease of its level indicates sufficient cerebral oxygen supply. Above results showed that low tidal volume combined with low-level PEPP could increase cerebral oxygen supply, reduce oxygen consumption of brain tissue, and avoid the occurrence of brain tissue hypoxia and related cognitive impairment after operation caused by oxygenation obstacle in laparoscopic surgery.

To sum up, it is concluded that when elderly patients receive laparoscopic surgery, low tidal volume combined with low-level positive end-expiratory pressure ventilation strategy can stabilize hemodynamic level and respiratory function as well as reduce systemic inflammatory state and the effect on cerebral blood supply in patients; it's worth popularization in clinical practice in the future.

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