Ventilation with a low tidal volume vs. an intermediate tidal volume during pleural decortication

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OBJECTIVE: *This study aims to evaluate the effects of low tidal volume and positive end expiratory pressure (PEEP) combined with pressure-controlled ventilation-volume guaranteed (PCV-VG) ventilation on one lung ventilation (OLV) in patients with tuberculous destroyed lung (TDL).*
METHODS: *Patients of two groups were all treated with volume controlled ventilation (VCV) on two-lung ventilation, and the tidal volume was set to 8 ml/kg according to standard body weight, breath rate was set to 10-14 times/min, inspiration and expiration ratio was set to 1:1.5. During OLV, VCV was used in group C, and the tidal volume was set to 8 ml/kg; PCV-VG was given to group P patients, and the tidal volume was set to 6 ml/kg, followed by PEEP at 7 cm H_2O. Breath rate was set to 12-16 times/min, and inspiration and expiration ratio was set to 1:1.5 in both groups on OLV.*
RESULTS: P_{plat}, P_{peak} *and intrapulmonary shunt (Qs/Qt) were lower at T2 and T3 in group P, when compared to group C (P<0.05). At T2, T3 and T4, the oxygenation index (OI) increased, Qs/Qt decreased and arterial carbon dioxide partial pressure ($PaCO_2$) increased in group P (P<0.05). At T5, the concentration of IL-6, TNF-α and BNP decreased in group P.*
CONCLUSION: *Low tidal volume and PEEP combined with PCV-VG ventilation might be helpful for alleviating pulmonary injury in OLV, and reducing airway pressure and Qs/Qt during OLV in surgery.*

KEY WORDS: Destroyed lung, Low tidal volume, Low tidal volume, Positive end-expiratory pressure, Pressure-controlled ventilation, One lung ventilation

Introduction

At present, tuberculosis remains as the most common infectious disease in the world. Furthermore, tuberculosis is a serious threat to human health [1] and some patients may develop tuberculous destroyed lung (TDL). TDL seriously affects the patients' quality of life and threatens their lives [2]. Patients with TDL have a long history of illness, and the fatality rate can reach up to 61% [3]. Most patients with TDL suffer from severe lung injury. Most parts of the lung on the operative side lose part or all of their functions. The changes in pulmonary anatomy on the operative side often cause repeated pulmonary infections [4,5]. For some patients, surgical operation might be the only means of effective therapeutic management [6].

In recent years, with the advancement of medical technology, the mortality rate of patients undergoing thoracotomy has significantly decreased. However, there has been no significant reduction in the incidence of postoperative pulmonary complications (PPCs), such as pulmonary infection, acute lung injury, and acute respiratory distress syndrome (ARDS) caused by mechanical

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ventilation [1,2,7]. Moreover, lung injury after thoracotomy is the main cause of death in thoracic surgery [8]. A large number of literatures [9-13] have demonstrated that incorrect ventilation during an operation can lead to lung injury.

The mechanisms involved in lung injury during one-lung ventilation (OLV) might include pressure injury, volume injury, atelectasis injury, and biological lung injury caused by the above injuries [14]. During OLV in TDL patients, due to the traction by surgical operation and changes in airway anatomy, higher airway pressure and insufficient ventilation at the ventilatory side may occur during surgery, while lung injury and hypoxemia are prone to occur.

Patients with TDL usually have a long history, and suffer from serious lung lesions. Furthermore, most patients have bilateral lung injuries, and their lung functions significantly decrease. In addition, the secondary pulmonary infection after surgery might be fatal to patients. Hence, it is extremely important to protect the lung from injury and infection. Low tidal volume can reduce the mechanical ventilation injury [3].

Pressure-controlled ventilation-volume guaranteed (PCV-VG) [15], which means pressure regulated volume control (PRVC), is a new type of intelligent ventilation mode. PCV-VG conveys the preset tidal volume with the lowest pressure and decelerated flow. Furthermore, PCV-VG has both the advantages of volume control and pressure control. It can automatically adjust the pressure according to the changes in pulmonary compliance, which is more in line with the respiratory physiology of patients. During the OVL in healthy subjects 4-64-6, it has been demonstrated that PRVC could provide lung protection. Low tidal volume ventilation can significantly reduce airway pressure in OLV, and has been widely accepted in anesthesia, which can prevent barotrauma. However, it can easily lead to end-expiratory alveolar collapse and atelectasis. Positive end-expiratory pressure (PEEP) might prevent end-expiratory alveolar collapse and decrease the incidence of atelectasis.

Thus, the present study aims to investigate whether low tidal volume and PEEP combined with PCV-VG ventilation on OLV in patients with TDL during pleural decortication can reduce the mechanical ventilation injury, and therefore the incidence of perioperative cardiovascular complications and postoperative hypoxemia.

Subjects and Methods

Patients

The present study was approved by the Medical Ethics Committee of Beijing Thoracic Hospital Affiliated to Capital Medical University. All patients have provided a signed informed consent.

A total of 132 patients with tuberculous empyema, who underwent pleural decortication under general anesthesia from September 1, 2016 to August 31, 2018 in Beijing Thoracic Hospital Affiliated to Capital Medical University, were selected as the study population. Exclusion criteria: (1) patients who received long-term steroid hormone therapy before surgery; (2) patients with a history of right heart failure; (3) patients with an arterial blood peripheral oxygen saturation (SpO_2) of <90% before surgery; (4) patients with unstable hemodynamics during surgery, who were ineffective to drug therapy. The age of these patients ranged between 35-65 years old. Furthermore, their body mass index (BMI) was 17-28 kg/m^2, and their American Society of Anesthesiologists (ASA) grade was II or III. 12 cases were excluded: 9 cases with surgical mode changed during the operation; 1 case of hypoxemia during surgery; 2 cases with serious cardiovascular events during surgery.

Ventilation Protocol

These patients were randomly assigned into two groups according to the random number table: the protective lung ventilation group (group P) and the control group (group C).

After entering the operation room, the left upper limb venous access of these patients was routinely opened. Blood pressure, heart rate and oxygen saturation were routinely monitored, the left radial artery and right central jugular vein were punctured and catheterized under local anesthesia, and the bispectral index (BIS) of electroencephalography (EEG) was monitored during the operation.

Anesthesia induction: Next, 0.3 μg/kg of sufentanil and 0.1 mg/kg of midazolam were slowly and successively intravenously injected, and propofol was infused using a target-controlled infusion pump (TCI). The target serum concentration was 3.0-4.0 μg/ml. After the patient lost consciousness, 0.2 mg/kg of atracurium cisbenzenesulfonate was intravenously injected. Visible left double-lumen bronchial catheters were inserted for all patients (female, 35; male, 39). Intraoperative ventilation with an Ohmeda Avance CS 2pro anesthesia ventilator and pure oxygen inhalation were applied, and the oxygen flow was 3 L/min. During the double lung ventilation, tidal volume was 8 ml/kg (with reference to predicted body weight of the patient), respiratory rate was 10-14 times/min, and inspiratory-to-expiratory ratio was 1.0:1.5. During the OLV, respiratory rate was 12-16 times/min, inspiratory-to-expiratory ratio was 1.0:1.5, and PCV-VG was applied in group P, with a tidal volume of 6 ml/kg and PEEP was set at 7 cm H_2O. Volume-controlled ventilation was applied in group C, with a tidal volume of 8 ml/kg, and PEEP was set at 0 cm H_2O.

Maintenance of anesthesia: Propofol was infused by TCI during surgery to maintain a serum concentration of 2.0-3.5 μg/kg. When necessary, remifentanil hydrochloride

(target serum concentration of 2.5-3.0 ng/m1) by TCI and 5 mg of atracurium cisbenzenesulfonate were intravenously given to maintain the BIS within 40-60 and heart rate (HR) within 60-100 beats/min, and the fluctuation range of mean atrial pressure (MAP) was not more than 20% of the baseline value. When the MAP was higher than 20% of the baseline value and lasted more than one minute, and the effect of the depth of anesthesia was excluded, 12.5 mg of urapidil was intravenously injected. When the MAP was lower than 20% of the baseline value and lasted more than one minute, the infusion of 50 ml of liquid was ineffective within 5-10 minutes, and the effect of the depth of anesthesia was excluded, 6 mg of ephedrine was intravenously injected. If HR was less than 50 beats/min or more than 100 beats/min, 0.2 mg of atropine or 5 mg of esmolol was intravenously injected. All vasoactive agents may be repeatedly administered. If the circulation stability could not be maintained by the above managements, the patient was excluded from the present study. Peak pressure (P_{peak}), plateau pressure (P_{plat}) and dynamic total respiratory system compliance (Cdyn) were recorded and stored every five minutes through the bypass side flow monitoring system.

Patient-controlled intravenous analgesia (PCIA) was applied after surgery with 4 μg/kg of sufentanil and 10 mg of tropisetron diluted to 100 ml with natural saline. The background dosage was 2 ml/h, self-controlled dosage was 1 ml each time, and the locking time was 15 minutes.

Evaluation

Primary observation criteria: P_{plat}, P_{peak} and oxygenation index (OI). P_{peak}, P_{plat} and Cdyn were taken as the testing data at five minutes before OLV(T1), at 30 minutes after OLV (T2), immediate before chest closure (T3), and at 10 minutes (T4) after chest closure and bilateral lung ventilation in the lateral decubitus position. Arterial and venous blood was drawn for blood gas analysis at T1, T2, T3 and T4, and six hours after surgery (T5). The intrapulmonary shunt (Qs/Qt[%]) and OI value were calculated according to the following equation:

$Qs/Qt = (PAa - DO_2 \times 0.0331) / PA - aDO_2 \times 0.0331 + (CaO_2 - CvO_2)$

Secondary observation criteria: Venous blood was drawn at T1 and T5. The serum concentration of interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α) and brain natriuretic peptide (BNP, this was assayed by the laboratory department of Beijing Thoracic Hospital Affiliated to Capital Medical University) was determined by enzyme-linked immunosorbent assay.

Pulmonary complications observed at the first and seventh day after surgery: pulmonary infection, empyema, atelectasis, pleural effusion, postoperative hypoxemia, arrhythmia, and so on.

Statistical Analysis

SPSS 19.0 software was used for the statistical analysis. Quantitative data were expressed as mean ± standard deviation (x ± SD). In comparing measurement data, two-way repeated measures ANOVA with was used when the variance was homogeneous, while rank-sum test was used when the variance was not homogeneous. Repeated-measures designed variance analysis was used for intra-group comparisons. X2-test was used to compare categorical data. P<0.05 was considered statistically significant.

Results

There were no significant differences in general characteristics, including gender, age, weight, ASA grade and operation duration, intraoperative bleeding volume, and OLV time between the two groups (P>0.05, Table I).

The P_{peak} and P_{plat} in group C were significantly higher at T2 (P_{peak}: 21.1 ± 3.3 cm H_2O; P_{plat}: 20.3 ± 2.9 cm H_2O) and T3 (P_{peak}: 21.1 ± 3.3 cm H_2O; P_{plat}: 20.1 ± 2.5 cm H_2O), when compared with those at T1 (P_{peak}: 19.9 ± 2.6 cm H_2O; P_{plat}: 18.8 ± 2.6 cm H_2O) (P<0.05). The P_{peak} in group P significantly decreased at T2 (19.8 ± 2.9 cm H_2O) and T3 (19.9 ± 2.9 cm H_2O), when compared with those in group C (P<0.05). The P_{plat} in group P significantly decreased at T2 (19.0 ± 2.6 cm H_2O), when compared with those in group C (20.3 ± 2.9 cm H_2O) (P<0.05). The MAP increased significantly in group P at T3 (73.1 ± 9.4) and T4 (71.9 ± 10.2 cm H_2O), when compared with those in group C (T3: 67.3 ± 9.9 cm H_2O; T4: 65.9 ± 9.5 cm H_2O) (P<0.05, Table II).

Mechanics and hemodynamic index in patients during the surgery (Group C: n=60; Group P: n=60). Abbr.

Table I - *General characteristics of group C and group P.*

Item	Group P	Group C	P
Gender(male/female)	39/21	43/17	0.279
Age(year)	46.1±16.5	44.1±15.6	0.930
BMI	22.0±3.2	22.7±3.7	0.118
ASA grade(II/III)	22/38	27/33	0.229
FEV1/FVC	83.0±11.5	84.9±8.4	0.299
FEV1	2.15±0.58	2.21±0.61	0.345
MVV(%)	61.8±6.7	61.0±7.4	0.393
Anesthesia time(min)	221±51.4	226±58.3	0.318
OLV time(min)	195±34.6	188±28.9	0.089
Open the chest(Left/Right)	24/36	27/33	0.356
Urine volume(ml/kg/h)	0.92±0.18	0.94±0.19	0.117
Intraoperative blood transfusion(ml)	605±289	655±388	0.180
Intraoperative bleeding(ml)	652±356	597±299	0.082
Blood transfusion volume(ml)	2950±900	3013±941	0.395

TABLE II - *Basic ventilatory variables of group C and group P.*

Item	Group P	Group C	P
Ppeak (cm H_2O)			
T1	19.4±2.5	19.9±2.6	0.359
T2	19.8±2.9	21.1±3.3	0.028
T3	19.9±2.9	21.1±3.3	0.044
T3	19.3±2.3	20.0±2.9	0.206
Pplat (cm H_2O)			
T1	18.5±2.5	18.8±2.6	0.532
T2	19.0±2.6	20.3±2.9	0.022
T3	19.0±2.5	20.1±2.5	0.023
T4	18.6±2.4	19.0±2.4	0.421
CVP(mmHg)			
T1	11.7±2.0	11.7±1.7	0.957
T2	11.6±2.0	12.0±1.7	0.155
T3	10.6±1.9	11.8±1.7	0.001
T4	11.2±1.9	11.3±2.0	0.691
MAP(mmHg)			
T1	84.4±8.3	81.8±9.4	0.097
T2	76.8±12.1	74.2±12.3	0.257
T3	73.1±9.4	67.3±9.9	0.002
T4	71.9±10.2	65.9±9.5	0.002

TABLE III - *Basic hemodynamic variables of group C and group P.*

Item	Group P	Group C	P
Ph			
T1	7.375±0.037	7.370±0.035	0.280
T2	7.372±0.038	7.360±0.041	0.289
T3	7.363±0.037	7.346±0.031	0.031
T4	7.379±0.049	7.372±0.041	0.279
OI			
T1	431.2±31.7	419.1±38.8	0.059
T2	200.4±49.1	217.6±66.8	0.088
T3	191.1±48.4	157.7±35.9	0.000
T4	320.4±101.1	271.0±118.6	0.007
$PaCO_2$ (mmHg)			
T1	38.8±4.8	37.7±4.4	0.144
T2	42.8±4.5	37.0±4.1	0.000
T3	40.3±3.7	36.7±3.8	0.000
T4	36.9±2.8	35.9±2.8	0.102
Qs/Qt%			
T1	10.6±2.7	11.0±4.0	0.432
T2	19.8±5.9	20.5±4.6	0.428
T3	16.3±5.2	17.7±5.7	0.332
T4	14.1±4.6	15.9±5.1	0.025

P_{plat}: plateau pressure; MAP: mean atrial pressure; CVP: central venous pressure; P_{peak}: peak pressure.

The OI in group P significantly increased, while at T3 (191.1 ± 48.4) and T4 (320.4 ± 101.1) when compared to those in group C (T3: 191.1 ± 48.3; T4: 320.4 ± 101.1) (P<0.05); $PaCO_2$ significantly increased in group P at T2 (42.8 ± 4.5 cm H_2O) and T3(40.3 ± 3.7 cm H_2O), when compared to those at T1 (38.8 ± 4.8 cm H_2O) (P<0.05), At T2 and T3, the $PaCO_2$ in group P significantly increased, when compared to those in group C (T3: 36.7 ± 3.8 cm H_2O; T4: 35.9 ± 2.8 cm H_2O) (P<0.05, Table III).

TABLE IV - *Concentration of TNF-a, IL-6 and BNP of group C and group P (x ± s).*

Item	Group P	Group C	P
TNF-α (pg/ml)			
T1	26.0±10.9	27.5±9.5	0.256
T5	49.7±15.5	59.0±18.3	0.005
IL-6 (pg/ml)			
T1	26.6±7.5	27.8±9.4	0.394
T5	45.2±12.3	54.3±15.7	0.0101
BNP (ng/L)			
T1	300.1±132.4	331.6±145.5	0.205
T5	472.0±180.3	569.6±128.9	0.001

TABLE V - *Comparisons of perioperative complications between two groups (n=60).*

Item	Group P	Group C	P
Pulmonary complications	13	21	0.078
ARDS	2	1	
Atelectasis	3	4	
Hypoxemia	7	16	
Bronchopleural fistula	1	0	
Cardiovascular complications	23	38	0.005
Sinus tachycardia	14	23	
Frequent atrial fibrillation with atrial fibrillation	3	5	
Sinus bradycardia	2	3	
Frequent ventricular premature	4	7	

The serum concentration of TNF-α, IL-6 and BNP significantly increased in these two groups at T5 (group P: TNF-α: 49.7 ± 15.5 pg/ml, IL-6: 45.2 ± 12.3 pg/ml, BNP: 472.0 ± 180.3 ng/L; group C: TNF-α: 59.0 ± 18.3 pg/ml, IL-6: 54.3 ± 15.7 pg/ml, BNP: 569.6 ± 128.9 ng/L), when compared to those at T1 (group P: TNF-α: 26.0 ± 10.9 pg/ml, IL-6: 26.6 ± 7.5 pg/ml, BNP: 300.1 ± 132.4 ng/L; group C: TNF-α: 27.5 ± 9.5 pg/ml, IL-6: 27.8 ± 9.4 pg/ml, BNP: 331.6 ± 145.5 ng/L) (P<0.05). At T5, the concentration of TNF-α, IL-6 and BNP of group P was higher than those in group C (P<0.05, Table IV). Compared to group C, the incidence of cardiovascular events was lower in group P after surgery (P<0.05, Table V).

Discussion

In the present study, the P_{plat} and P_{peak} significantly increased in group C during OLV. The OI in group P were better than that in group C at T3 and T4, and

the incidence of peri-surgical cardiovascular complications was lower. The MAP in group P at T3 and T4 increased to nearly normal levels. The $PaCO_2$ in group P during OLV significantly increased. At T3 and T4, the OI significantly increased in group P, when compared to that in group C. There was a significant increase in the concentration of TNF-α, IL-6 and BNP in group C after surgery. In group C, there were nine patients with the P_{plat} and P_{peak} levels higher than 30 cm H_2O during the surgery.

Pressure injury plays a key role in OLV lung injury in patients with TDL. Hence, it is particularly important to reduce airway pressure in OLV in patients with TDL. During the OLV in the present study, patients with protective lung ventilation had maintained lower P_{plat} and P_{peak} levels, since higher P_{plat} and P_{peak} could lead to lung injury and aggravate the intrapulmonary shunt 16. The case analysis of pulmonary infection conducted by Jeon K et al. [17] revealed that the risk of acute lung injury increased by 2.32% for each increase in airway pressure of 1 cm H_2O, and in ARDS patients ARDS, the value of P_{plat} and P_{peak} greater than 30 cm H_2O could cause lung injury. P_{plat} is positively correlated to pressure injury. The incidence of pressure injury is very low when P_{plat} is lower than 25 cm H_2O, while the incidence of pressure injury might significantly increase when P_{plat} is higher than 29 cm H_2O [8,18,19]. Studies showed that high airway pressure could lead to lung injury. In the control group, nine patients had both P_{plat} and P_{peak} higher than30 cm H_2O. In the protective lung ventilation group, both P_{plat} and P_{peak} significantly decreased during OLV, with the P_{plat} and P_{peak} both lower than30 cm H_2O. These aicators for monitoring the stability of the circulatory system. Compared with traditional hemodynamic monitoring, and as a functional dynamic hemodynamic monitoring index, the variation of stroke volume measured by the FloTrac/Vigileo system has high specificity (93%-96%) and sensitivity (79%-94%) in estimating the circulating blood volume. Furthermore, it can accurately monitor the change in blood volume in patients, and guide clinical decision-making and rehydration therapy [20,21]. The CI and MAP in group P were higher than those in group C during OLV, which indicates that low tidal volume ventilation combined with the PCV-VG ventilation mode has less influence on a patient's blood circulation during OLV, and might be more beneficial for the stability of blood circulation in patients.

The OI at six hours after the surgery in patients in group P was higher than that in patients in group C, and the incidence of hypoxemia was significantly lower. The possible reason might be that the OLV mode in group P was more in line with the respiratory physiology of these patients. Furthermore, the lower airway pressure maintained during surgery might have alleviated the occurrence of lung injury. After the surgery, these patients maintained a better gas exchange and OI, which prevented the accumulation of CO_2.

OLV may cause the release of inflammatory cytokines and aggravate lung injury [8,22]. Both TNF-α and IL-6 are cytokines in the early stage of lung injury, and the monitoring of changes in TNF-α and IL-6 concentration may be regarded as the observation criteria in lung injury [12,23-24]. Schãoer et al. [25] reported that the changes of TNF-α and IL-6 might be detected in alveolar lavage fluid at one hour after mechanical ventilation. Inflammatory cytokines may enter the blood circulation, and the changes of related cytokines may be detected in blood. In the present study, TNF-α and IL-6 significantly increased in group C, which suggests that lung injury was more serious in group C during OLV.

There was no occurrence of hypoxemia in both groups, which was completely different from the incidence of 5-10% of hypoxemia during OLV reported by Hadrien Roz et al. [26]. The possible reason might be that most of the lung functions in the present study were lost before surgery, and the TDL resection reduced the intrapulmonary shunt, thereby increasing oxygenation. Furthermore, higher CO_2 and lower pH were maintained in group P during the surgery, while the relatively higher $PaCO_2$ maintained during the mechanical ventilation might increase the survival rate of patients 3, 27. Giorgio D R et al. [18,28] reported that a moderately high level of $PaCO_2$ during OLV was conducive to the release of blood O_2 to tissues. $PaCO_2$ below 70 cm H_2O is tolerable, and has certain lung protective effects. However, there was no difference in $PaCO_2$ between the two groups at six hours after the surgery, which means that there was no $PaCO_2$ accumulation in group P.

The BNP in group P was significantly lower than that in group C. Clinically, BNP has been regarded as an important monitoring criterion routinely used in the prognosis of acute and chronic heart failure [29,30]. The incidence of heart failure increases as post-operative BNP becomes higher than 450 ng/L. In the present study, the incidence of cardiovascular events was lower in group P after surgery, and the possible reasons might be that the application of protective ventilation in group P could have alleviated the lung injury, allowing patients to maintain better oxygenation state. Thus, the patient's internal environment was closer to normal pH, which ensured the stability of the internal environment. Patients in group P maintained a better gas exchange. Furthermore, patients in this group maintained a better PaO_2 and pH, which lead to a relatively stable internal environment, and a decrease in occurrence of cardiovascular events.

Limitations of the study

The limitations of the present study were as the follows: First, the patients included in the present study all had TDL, and patients with concomitant diseases might have led to increased levels of related inflammatory cytokines, which would inevitably lead to confounding factors.

Second, the present study was a randomized controlled trial, and no blind method was adopted, which could inevitably have resulted in systematic errors. Third, all patients in the present study had a long operation time. Surgery and intraoperative blood transfusion would have an impact on the data tested.

Conclusion

During OLV in patients with TDL, the ventilation mode of low tidal volume and PEEP combined with PCV-VG is very important, which might reduce airway pressure and lung injury, improve the OI during OLV during surgery, and it appears to be a save of the occurrence of cardiovascular complications during the perioperative period.

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Riassunto

Questo studio mira a valutare gli effetti del volume corrente basso e della pressione positiva di fine espirazione (PEEP) combinati con la ventilazione a volume garantito di ventilazione controllata (PCV-VG) su una ventilazione polmonare (OLV) in pazienti con polmone distrutto tubercolare (TDL).

Metodi: I pazienti di due gruppi sono stati tutti trattati con ventilazione a volume controllato (VCV) con ventilazione a due polmoni e il volume corrente è stato impostato su 8 ml / kg in base al peso corporeo standard, la frequenza respiratoria è stata impostata su 10-14 volte / min , il rapporto tra inspirazione ed espirazione è stato impostato su 1: 1,5. Durante OLV, VCV è stato utilizzato nel gruppo C e il volume corrente è stato impostato a 8 ml/kg; PCV-VG è stato somministrato ai pazienti del gruppo P e il volume corrente è stato impostato a 6 ml/kg, seguito da PEEP a 7 cm H_2O. La frequenza respiratoria è stata impostata su 12-16 volte/min e il rapporto tra inspirazione ed espirazione è stato impostato su 1: 1,5 in entrambi i gruppi con OLV.

Risultati: P_{plat}, P_{peak} e shunt intrapolmonare (Qs / Qt) erano inferiori a T2 e T3 nel gruppo P, rispetto al gruppo C (P <0,05). A T2, T3 e T4, l'indice di ossigenazione (OI) è aumentato, Qs/Qt è diminuito e la pressione parziale di anidride carbonica arteriosa (paco2) è aumentata nel gruppo P (P <0,05). A T5, la concentrazione di IL-6, TNF-α e BNP è diminuita nel gruppo P.

Conclusione: il basso volume corrente e la PEEP combinati con la ventilazione PCV-VG potrebbero essere utili per alleviare il danno polmonare in OLV e ridurre la pressione delle vie aeree e Qs/Qt durante OLV in chirurgia.

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