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A Case of Hypoxemia Occurred During One-Lung Ventilation

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Abstract

Background: In thoracic surgery, One Lung Ventilation (OLV) is a common technique to maintain ventilation and oxygenation. Hypoxemia during OLV is not rare, and if not detected in time or handled improperly, it may cause serious consequences and threaten the life of the patient. In the perioperative period, various factors including surgery, anesthesia and patients themselves may lead to the occurrence of hypoxemia during OLV. How to prevent and reduce the occurrence of hypoxemia in patients with OLV is a concern of anesthesiologists during the perioperative period.

Methods: A case report study with analysis.

Results: We report a case of hypoxemia during OLV in an elderly patient who underwent video-assisted thoracoscopic wedge resection of a mass in the left upper lung plus lymphatic dissection, which was successfully corrected by associated anesthesia management measures.

Conclusion: Hypoxemia during one-lung ventilation is not uncommon. For patients requiring one-lung ventilation during the operation, the anesthesiologist shall fully evaluate the patient's condition, and formulate a reasonable anesthesia plan according to some predictors of hypoxemia, so as to prevent or reduce the incidence of hypoxemia during one-lung ventilation and ensure the safety of the patient's life.

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Introduction

OLV is often used in thoracic surgery. It prevents the flow of secretions or blood from the operative side to the healthy side of the lung, ensures airway patency, and prevents expansion of the operative side of the lung, providing the best surgical field of view, and reduces damage to the parenchyma of the lung.

However, OLV may lead to intraoperative hypoxemia, the incidence of which was reported to be 5% to 10% [1]. Improper placement of the Double-Lumen Endobronchial Tube (DLT) is the most common cause of hypoxemia during OLV. The main mechanisms of hypoxemia in OLV are arteriovenous shunt and ventilation/perfusion (VA/Q) disorders in the lung. The non-ventilated side of the lung has blood flow but no ventilation, which is likely to cause oxygenation disorder. Atelectasis caused by anesthesia in the ventilated side of the lung can further reduce oxygenation by reducing ventilatory lung volume and inducing VA/Q mismatch [2,3].

It is a challenge for anesthesiologists to develop a set of perioperative management plans to prevent and reduce the occurrence of hypoxemia during OLV in patients undergoing chest surgery and to protect the life safety of patients.

Case Presentation

The patient, male, 76 years old, weighed 89 kg, had a body mass index of 29.1 kg/m^2. He underwent video-assisted thoracoscopic wedge resection of left upper lung mass plus lymphatic dissection due to left lung occupation. Previous history of hypertension, Blood Pressure (BP) up to 150/100 mmHg, taking losartan potassium and hydrochlorothiazide tablets antihypertensive therapy, blood pressure fluctuation was detected at 140~150/90~95 mmHg. The blood glucose was high for 2 years, and the fasting blood glucose fluctuated between 6~6.5 mmol/L. Diabetes was not clearly diagnosed. The history of atrial fibrillation was 3 years. Warfarin and aspirin were successively used for anticoagulant and antiplatelet therapy, and then self-deactivated. When admitted, a drug called metoprolol succinate sustained-release tablets was taken orally to control ventricular rate. Echocardiography showed enlargement of the left and right atrium, thickening of the base of the ventricular septum, moderate tricuspid and mitral regurgitation, calcification of the aortic valve, mild pulmonary hypertension (about 36 mmHg), and an EF value of 61%. The pulmonary function was low at the maximum volume, F-V curve showed limited airflow in small airway, and moderate mixed ventilation dysfunction. The dynamic electrocardiogram showed sustained atrial fibrillation, with the longest R-R interval of 2.16s, a total of 67 ventricular premature beats, and intermittent T-wave depression. He was accepted in ASA grade-III for surgery.

When entering the operating room, there was ABP of 124~146/86~92 mmHg, heart rate of atrial fibrillation, pulse oxygen saturation (SpO_2) of 100% under pure oxygen condition.

Midazolam was given 6 mg, vecuronium 12 mg, fentanyl 0.75 mg and etomidate 20 mg for general anesthesia induction. After 5 min, right-sided DLT (35Fr) was inserted with good ventilation. The fiberoptic bronchoscopy confirmed good positioning of the catheter, with machine-controlled breathing, Respiratory Rate (RR) 12 times / min, oxygen flow rate 2 L/min, and double-lung ventilation. Before surgery, the body position changed from supine to right lateral position, the main tube was well aligned by fiberoptic bronchoscopy, and Arterial Blood Gas (ABG) analysis was performed at p^H 7.40, $PaCO_2$ 41 mmHg, PaO_2 231 mmHg, SpO_2 100%.

At the beginning of the operation, right lung ventilation was given, with Tidal Volume (VT) 350 ml, RR 14 times/min, and airway pressure of 25 mmHg. Intravenous infusion of 2% propofol 20 mL/h, vecuronium 3 mg/h, remifentanil 0.5 mg/h, sevoflurane 1% intermittent inhalation to maintain general anesthesia. The BP fluctuated between 88~120/57~70 mmHg. When the SBP was lower than 90 mmHg, sevoflurane was stopped, and phenylephrine was given 80 ug intravenous injection. Meanwhile, propofol was reduced to 16 mL/h and remifentanil was 0.3 mg/h, and the blood pressure rose to normal. SpO_2 remains at 96% to 98%.

At about 40 min of OLV, SpO_2 of the patient decreased slowly from 96% to 86%, BP fluctuated between 92~100/55~62 mmHg, and P peak was 29 mmHg. The anesthesiologist immediately used a fiberoptic bronchoscopy to confirm that the catheter was in place and artificially controlled breathing. SpO_2 then rose, to about 90%. VT was increased to 450 ml and ventilation was controlled by ventilator. ABG analysis showed pH 7.38, $PaCO_2$ 44 mmHg, PaO_2 56 mmHg, SpO_2 88%. The patient's PaO_2 was less than 60 mmHg, and the anesthesiologist considered the patient to have hypoxemia. The patient was given short-term two-lung ventilation and then single-lung ventilation, followed by light anesthesia, discontinuation of inhaled anesthetics, reduction of propofol to 12 mL/h, remifentanil 0.15 mg/h, intermittent intravenous injection of phenylephrine 100 ug to maintain the BP at 120~140/70~80 mmHg, and the patient's SpO_2 eventually rose to 100%. After surgical removal of the diseased lung, bilateral ventilation was performed. After the operation, the double lumens were changed into a single tube. The operation lasted for 1 h and 35 min, with 20 mL of bleeding, 300 mL of urine, 1500 mL of infusion including 500 mL of crystal fluid and 1000 mL of colloidal fluid. After the operation, the patient's vital signs were stable, and the ABG analysis was normal.

Discussion

In this case, SpO_2 decreased slowly about 40 min after the operation began, with a minimum of 86%. The P peak only increased 5 mmHg compared with the previous time, and no significant change in hemodynamics was observed. After a series of relevant corrective operations, SpO_2 gradually returned to the normal level. Therefore, it was considered that the reason for the intraoperative hypoxemia in this patient was increased intrapulmonary shunt during OLV and the imbalance of VA/Q. Hypoxic Pulmonary Vasoconstriction (HPV) is the unique protective mechanism of pulmonary vessels, which can transfer the blood flow in the lungs from the lung tissues with low alveolar oxygen tension to the better pulmonary ventilation area, reducing intrapulmonary bypass and systemic hypoxia. Studies have reported [4] that the maximum response of HPV occurs 10~15 min after OLV. The preoperative pulmonary function of the patient was not severe. In the early stage of the operation, the patient did not show hypoxia due to the existence of the pulmonary circulation compensation mechanism for hypoxia. As the duration of one-lung ventilation is prolonged, due to the influence of anesthetic factors, HPV is inhibited, and VA/Q imbalance appears, presenting as obvious hypoxemia.

A number of factors may help predict oxygenation during OLV in the perioperative period. The possible reasons for hypoxemia in this patient are as follows: First, the patient is older, and some of the regulatory compensation mechanisms for hypoxia in the body are relatively imperfect. Second, the patient had a BMI of 29.1 kg/m^2 and was overweight. Patients with obesity due to their own physiological and pathological changes will affect ventilation and oxygenation. In one study [5], 14 obese patients with a BMI greater than 30 kg/m^2 who needed OLV during thoracic surgery had more intraoperative and postoperative hypoxemia than non-obese patients. Third, his lesion was located in the left upper lung, and wedge-shaped resection of the left upper lung tumor was performed. Compared with the large lumps or large bubbles on the surgical side, the patients had more perfusion into the non-dependent lung during OLV, and these patients were prone to transient hypoxemia during the operation. Fourth, intermittent inhalation of sevoflurane may cause hypoxemia. The effect of inhaled anesthetics on hypoxemia under OLV is controversial. Studies have shown that inhaled anesthetics sevoflurane and isoflurane have been shown to inhibit HPV, thereby increasing hypoxemia [6]. Other studies have reported [7] that inhaled anesthetics can increase intrapulmonary shunt by inhibiting HPV on the one hand. On the other hand, by affecting cardiac output, reducing non-ventilated pulmonary blood flow, reducing the fraction of flow, and thus generally having no significant effect on oxygenation.

These factors may cause the occurrence of intraoperative hypoxemia with the prolongation of operation time. When intraoperative hypoxemia occurs, it should be corrected immediately and the cause identified. Upon the occurrence of hypoxemia, the anesthesiologist immediately confirmed the presence of the catheter through fiberoptic bronchoscopy, eliminated the factor of hypoxemia caused by respiratory circuit disturbance, and determined that the increased intrapulmonary shunt during OLV and the VA/Q imbalance may have caused the hypoxemia. After timely treatment, SpO_2 gradually returned to the normal level until the end of the operation, avoiding the further progress of hypoxemia.

In order to prevent and reduce the occurrence of hypoxemia during one-lung ventilation, some measures need to be taken:

Improve preoperative lung function

ABG analysis during preoperative examination or bilateral ventilation prior to OLV revealed that abnormally low arterial oxygen partial pressure may be a reliable indicator of pulmonary dysfunction, predicting hypoxemia during OLV. Slinger et al. [8] found that the level of PaO_2 during spontaneous respiration and even during dual-lung ventilation was strongly positively correlated with the level of PaO_2 during OLV. Preoperative improvement of lung function includes physical therapy, medication to dilate bronchi and expel secretions, which can not only reduce postoperative pulmonary complications, but also improve oxygenation during OLV.

Focus on pulmonary perfusion

Since intrapulmonary shunt depends on the percentage of un-oxygenated blood as a percentage of cardiac output, the less pulmonary perfusion with stuffy lung, the more pulmonary perfusion with ventilatory lung, and the higher the PaO_2 at OLV. Preoperative measurements of perfusion distribution between the two lungs may help predict hypoxemia during OLV. Many patients undergoing major thoracic surgery may have had a perfusion scan prior to surgery, so anesthesiologists need to take into account the scan results and be prepared in advance.

Ventilation strategy

The ventilation strategy most suitable for the needs of patients is formulated according to the patient's condition and the best available clinical evidence. Guidance [9] indicates that Pressure Control (PC) or Pressure Control Guaranteed Volume (PCV-PG) can be used for pneumonectomy patients with OLV. Protective mechanical ventilation is recommended with tidal volume of 6~8 mL/kg, Positive End Expiratory Pressure (PEEP) of 5 cm H_2O, and controlled P peak <40 cm H_2O. Improving lung compliance to obtain better lung ventilation under single-lung ventilation conditions may improve hypoxemia in patients. By relatively prolonged inspiratory time, ventilation volume can be increased, airway pressure can be reduced and lung compliance can be improved. It has been reported that 1:1 setting of Inspiration and Expiration ratio (I:E) can reduce airway pressure and improve lung compliance compared to 1:2 [10], which is consistent with the recommendations in the guidelines. The guidelines [9] also suggest that Continuous Positive Airway Pressure (CPAP) or high frequency ventilation on the operative side of the lung can reduce the flow of blood in the operative side of the lung and improve oxygenation, which may be beneficial to improve short-term oxygenation in patients with lobectomy and single-lung ventilation.

Drug selection

Intravenous infusion of dexmedetomidine combined with inhalation of isoflurane enhanced HPV and improved oxygenation during OLV [11]. Propofol or Isoflurane appears to have no significant effect on arterial oxygenation and can be used as an appropriate anesthetic for thoracic surgery to normalize the intraoperative CO_2 gradient range [12].

Conclusion

For patients requiring intraoperative OLV, anesthesiologists should fully understand the physiological functions of the patients in the preoperative evaluation, predict the influencing factors that may cause intraoperative hypoxemia, and formulate a reasonable anesthesia management plan to reduce the occurrence of intraoperative hypoxemia. When hypoxia occurs in patients with OLV during the operation, it should be corrected immediately, and the etiology be diagnosed quickly, so as to ensure the normal oxygenation and life safety of patients during the anesthesia operation.

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