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Research Progress on the Current Status and Intervention Strategies of Hypoxaemia in General Anaesthesia Patients during the Postoperative Awakening Period

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Abstract: ***To introduce the current situation of the occurrence of postoperative hypoxemia during the awakening period of general anesthesia patients, to analyze the influencing factors of the occurrence of hypoxemia during the awakening period of general anesthesia patients, and to summarize the intervention strategies of hypoxemia during the awakening period of general anesthesia patients, with a view to promoting the medical personnel's understanding of the risk factors of hypoxemia during the awakening period of general anesthesia patients, and to provide references for the development of reasonable intervention programs in the future.***

Keywords: General anesthesia, Awakening period, Hypoxemia, Influencing factors, Interventions, Review.

1. Introduction

Post-Anesthesia Care Unit (PACU) plays a crucial role in the perioperative anesthesia process, undertaking the resuscitation and extubation of patients after general anesthesia. Early postoperative hypoxemia is the most common anesthetic complication in PACU. Previous studies have shown that the incidence of postoperative hypoxemia in the PACU of general anesthesia patients is 26.7%-42.3% [1,2]. The occurrence of hypoxemia in the PACU can affect the regression and prognosis of patients, prolong their hospital stay, lead to an increase in hospitalization costs, and even increase the incidence of perioperative arrhythmia, myocardial ischemia, neurological dysfunction, and other multiorgan dysfunction syndromes, which can be life-threatening in severe cases [3]. Therefore, anesthesia recovery room nursing staff actively analyze relevant risk factors, early identification of high-risk patients, and timely adoption of intervention measures are of great significance to reduce the incidence of hypoxemia in patients in the PACU and to protect patients' life safety. This paper analyzes the current situation of hypoxemia during the awakening period of patients after general anesthesia and the influencing factors, and summarizes the relevant intervention strategies, aiming to provide a basis for reducing hypoxemia in PACU patients.

2. Current Status of Hypoxemia during Postoperative Awakening in Patients under General Anesthesia

A global consensus conference in June 2021 updated the definition of acute respiratory distress syndrome (ARDS) and broadened the diagnostic criteria for ARDS, with hypoxemia defined as PaO_2: $FiO_2 \le 300$ mmHg or SpO_2: $FiO_2 \le 315$ mmHg measured by pulse oximetry while $SpO_2 \le 97$ percent [4];The early stage of awakening from general anesthesia is a period of variable conditions, and patients often encounter various adverse conditions, and the awakening stage after general anesthesia is a high-risk period in which hypoxemia is prone to occur. Most of the hypoxemia events occurred within 20 minutes after the patients were transferred to PACU, and the incidence rates of hypoxemia in 0min, 5min, 10min, 15min, and 20min of transfer to PACU were 86.6%, 75.2%, 47%, 26.8%, and 22.8%, respectively [5]. Whereas mild hypoxemia (SpO_2<90%) occurred in 17% of patients, severe hypoxemia (SpO_2<85%) occurred in 6.6% of patients [6].

3. Factors Influencing Hypoxemia during Postoperative Awakening in Patients under General Anesthesia

3.1 Patient Susceptibility Factors

In the risk assessment of hypoxemia in the PACU, the risk of hypoxemia is highly dependent on individual differences in patients. In addition to the intuitive indicators of age and body mass index, the patient's underlying disease and overall physiologic functional status are important factors that cannot be ignored. Therefore, understanding the patient's overall health status is a critical step in the prevention and management of hypoxemia in the PACU.

3.1.1 Age

ANDUALEM et al. [7] showed that, Low incidence of postoperative hypoxemia in patients <55 years of age or younger. Age ≥55 years is an independent risk factor for developing hypoxemia in the PACU [1]. This is because vascular reactivity decreases with age, leading to inadequate perfusion of the body's blood and predisposing it to hypoxemia [8]. Secondly, in elderly patients, lung elasticity decreases, closure capacity increases, and postoperative alveolar collapse ultimately causes hypoxemia [9].

3.1.2 Body Mass Index (BMI)

KENDALE et al. [10] showed that the incidence of postoperative hypoxemia in patients with normal BMI was 16%, the incidence of hypoxemia in patients with BMI>30kg/m^2 was 28%, and the incidence of hypoxemia in patients with BMI>40kg/m^2 was as high as 35%. This is because obese patients chest wall hypertrophy limits the normal movement of the diaphragm and chest and abdomen, causing an increase in intrapulmonary shunt, resulting in hypoxemia; secondly, obese patients with high basal body oxygen consumption, in the role of surgical trauma and anesthetics, the body's oxygen consumption will be further aggravated, and postoperative patients in the general anesthesia awakening period of weakened cardiorespiratory function, it is difficult to meet the demand for oxygen, so it is easy to occur in hypoxemia [17,18].

3.1.3 Combined High Blood Pressure

A prolonged hypertensive state may disturb the patient's hemodynamic homeostasis, which in turn induces adaptive changes in myocardial structure (myocardial remodeling) and results in an increased myocardial demand for oxygen. As a result, hypertensive patients are more susceptible to decreased oxygen saturation, which in turn may induce hypoxemia [11].

3.2 Surgical Factor

3.2.1 Surgical Position

When lying supine, abdominal contents may cause some compression of the diaphragm, limiting the amplitude of diaphragmatic movement, thereby reducing the expansion and contraction capacity of the lungs and leading to decreased ventilation. At the same time, the supine position may affect the distribution of blood flow in the lungs, resulting in a relative lack of perfusion in some lung regions and affecting the efficiency of gas exchange. In addition, the patency of the airway may be affected to some extent when lying supine, which may easily lead to an increase in respiratory resistance, further affecting the inhalation of oxygen and the excretion of carbon dioxide. Some studies have shown that supine position can increase the risk of hypoxemia [12]. The prone position helps to improve lung function and increase gas exchange efficiency in patients with hypoxemia by improving the ratio of lung ventilation to perfusion, optimizing the distribution of ventilation blood flow, decreasing gravity-dependent zone solidity, and decreasing alveolar surface-active substance depletion, among other mechanisms, thereby alleviating hypoxic symptoms. The use of the prone position reverses postoperative pulmonary atelectasis and helps to improve primary graft function limitation that may occur after lung transplantation surgery [13].

3.2.2 Surgical Time

The increased length of surgery directly results in the need to maintain patients under general anesthesia for longer periods of time, which in turn exacerbates the respiratory depressant effects of anesthesia medications, making it difficult for patients to obtain sufficient oxygen from the outside world, thus increasing the risk of developing hypoxemia. YANG et al. [14] found that delayed eating during surgery may increase the risk of postoperative pulmonary complications.

4. Interventions for Hypoxemia during Awakening in Patients Andergoing General Anesthesia

4.1 Position Management

Postural management is one of the important measures to prevent hypoxemia during the awakening period of general anesthesia. Studies have shown that appropriate body position can improve the ventilation and oxygenation function of patients [15]. The mechanism of action of prone ventilation as an effective measure to improve the oxygenation index of patients may be to improve lung tissue compliance and ventilation-blood flow ratios by reducing the compressive effect of the heart on the left lower lung, which in turn improves oxygenation function [16]. It also reverses postoperative pulmonary atelectasis and improves primary graft dysfunction after lung transplantation [17].

4.2 Pulmonary Resurgence

Lung resuscitation usually includes manual lung resuscitation and ventilator-driven lung resuscitation, and ventilator-driven lung resuscitation includes spirometry, pressure-controlled methods, and volume-controlled methods. All modes of lung resuscitation are effective in opening alveoli and improving oxygenation [18]. LEE et al. [19] compared ultrasound-guided lung resuscitation with conventional lung resuscitation in children under 6 years of age and showed that the ultrasound-guided group was more effective in preventing intraoperative pulmonary atelectasis with improved postoperative oxygenation. Each of the existing lung resuscitation methods has its own advantages and disadvantages, and the clinical work should be based on different clinical scenarios and patient-specific conditions to adopt appropriate lung resuscitation strategies, not only to ensure the patient's intraoperative lung protection effect, but also to pay attention to the patient's prognosis. More high-quality evidence is needed to inform the development of individualized lung resuscitation protocols in the future.

4.3 Percutaneous High-flow Oxygenation

Transcutaneous high-flow oxygenation is a method of improving tissue hypoxia by giving the patient a high concentration of oxygen inhalation, which can rapidly increase the patient's oxygen saturation level. SUN et al. [20] randomized patients transferred to the PACU after luminal rectal cancer surgery into two groups. The control group received conventional nasal cannula oxygen therapy and the observation group received high-flow nasal cannula oxygen therapy. Results In the observation group, lung ultrasound scores and incidence of pulmonary atelectasis at PACU discharge were significantly lower than in the control group, $p<0.001$), and no patients in the observation group developed hypoxemia in the PACU, whereas six patients in the control group did ($P=0.03$). The results of several studies have shown that transnasal high-flow oxygen delivery in patients with hypoxic respiratory failure improves oxygen saturation, reduces the incidence of unplanned ICU admissions, pulmonary atelectasis, vomiting, and aspiration, and has a significant advantage in increasing patient comfort and improving oxygen saturation [21–24], However, patients should always pay attention to their condition and physiological changes when using high-flow oxygenation devices for oxygen therapy, and at the same time accurately monitor the basic conditions of patients' respiration, blood pressure, heart rate, etc., so as to effectively reduce the application of high-flow humidified oxygen to the patients caused by other physiological diseases, and to avoid influencing the prognostic effect [25].

4.4 Apply Multiple Monitoring Methods for Early Identification

4.4.1 Oxygen Saturation Monitoring

Oximetry monitoring has become a routine means of monitoring respiratory function in postoperative patients. However, oximetry monitoring can be delayed by 30-60s due to perfusion delays, interference, and measurement reanalysis [26]. Oxygen saturation monitoring also often results in false alarms due to patient finger movement or problems such as dislodging and interference. Some studies have shown that the incidence of false alarms on oxygen saturation can be as high as 41.2%, and long-term false alarms can lead to alarm desensitization and fatigue of healthcare personnel, thus disabling the alarm, lowering the volume, adjusting the upper and lower alarm limits, or even ignoring the alarm directly [27]. Substantially increase the safety risk. At the same time, decreased oxygen saturation is the ultimate manifestation of insufficient pulmonary ventilation, and by the time a patient's oxygen saturation is decreased, there may already be severe carbon dioxide accumulation. Simply monitoring pulse oximetry is no longer sufficient to meet the needs of clinical safety.

4.4.2 End-expiratory Carbon Dioxide Monitoring

End-expiratory carbon dioxide partial pressure monitoring is a noninvasive monitoring method that reflects the patient's direct and immediate ventilation, enabling supplemental monitoring of oxygen saturation [28]. GAVITT [29] and others constructed a continuous carbon dioxide monitoring program in the PACU, which can shorten the length of a patient's stay in the PACU and detect impending respiratory depression or failure earlier than pulse oximetry alone. The monitoring can detect and manage early onset of abnormal respiratory events in a timely manner, prevent further deterioration of the condition, and better ensure the safety of the patient during the awakening period.

4.4.3 Respiratory Volume Monitoring

Respiratory volume monitoring can provide real-time changes in minute ventilation, tidal volume and respiratory rate of patients whose endotracheal tubes have been removed, so that respiratory depression and asphyxia can be detected in a timely manner, GALVAGNO et al. [30] suggested that monitoring a patient's respiratory volume status can detect respiratory amnesia or respiratory depression earlier and reduce the number of patients with abnormal oxygen saturation due to insufficient pulmonary ventilation but more prone to carbon dioxide accumulation compared to oxygen saturation monitoring, which is commonly used in clinical practice. Respiratory volume monitoring can assist oxygenation and provide early warning, and even reduce the number of oxygen saturation vacation alarms. However, respiratory volume monitoring causes intense patient discomfort, and therefore its clinical dissemination remains difficult. Even though there are several non-invasive ways to monitor patients' respiratory function available in the clinic, each type of monitoring has its limitations of use and cannot comprehensively and objectively evaluate patients' oxygenation and ventilation. Therefore, when invasive monitoring is implemented in patients or when conditions such as carbon dioxide accumulation occur, timely arterial blood gas analysis is still needed to clarify the diagnosis and guide further treatment.

In summary, positional management, pulmonary reexpansion, transcutaneous high-flow oxygenation and application of multiple methods of detection are important measures for hypoxemia intervention in general anesthesia patients during the awakening period. By implementing these measures, the occurrence and development of hypoxemia can be effectively prevented and treated, and the quality of recovery and prognosis of patients can be improved.

5. Conclusion

The incidence of hypoxemia in general anesthesia patients during the awakening period is high and the pathogenesis is complex, which is affected by age, body mass index, comorbidities, surgery time and other factors. In order to reduce the risk of hypoxemia in general anesthesia patients during the awakening period, the comprehensive use of postural adjustment, pulmonary reanimation technology, oxygen therapy support and a variety of monitoring means for early identification and intervention has become a hot spot and direction of current research, but most of the studies are in the exploratory stage, the research effect is inconsistent, and has not been widely promoted and verified. In the future, personalized therapeutic care plans can be developed for general anesthesia patients with hypoxemia during the awakening period from an evidence-based perspective. Further promote the scientific and refined development of this research field.

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