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Air Embolism: A Severe Complication of Hysteroscopic Surgery

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Abstract: Air embolism is one of the complications of hysteroscopy. When air enters the circulatory system to block blood vessels, it will lead to embolism, and even endanger the life of patients in serious cases. The prognosis of patients can be significantly improved through the rapid diagnosis and timely treatment of air embolism. Since most air embolism is iatrogenic, operators should not only make preoperative preparations, but also be familiar with the symptoms and signs of air embolism. Once air embolism is suspected, the operator must immediately observe the patient's vital signs and hemodynamics and immediately stop the operation and carry out treatment to prevent further deterioration of the condition when the situation is critical. Based on the clinical cases of air embolism in recent years and relevant research and analysis, this paper summarizes the pathogenesis, clinical manifestations, auxiliary examination, prevention and treatment of air embolism, so as to provide reference for clinical prevention and treatment of air embolism.

Keywords: Hysteroscopy, Air Embolism, Diagnosis, Treatment

1. Introduction

Hysteroscopy is a common gynecological examination technology, which allows us to clearly observe the changes in the uterus during operation. Because of its minimally invasive and convenience, it is widely used in various gynecological operations. Medical workers should also pay attention to the complications while using hysteroscopy. Gas embolism is one of the most serious complications of hysteroscopy. It can produce fatal consequences when the situation is critical. Therefore, timely detection and prompt intervention are very important to reduce incidence rate and mortality. This paper reviews the current research results related to air embolism, mainly including pathogenesis, clinical manifestations, auxiliary examination and treatment methods, hoping to provide some ideas for the clinical treatment of air embolism.

2. Pathogenesis

Some gynecological operations require hysteroscopy into the uterus, using liquid to expand the uterine cavity for visualization and energy to remove tissue. Gas can enter the blood vessels through the open cervix or when operating instruments. According to the difference of entering blood vessels, it can be divided into venous air embolism and arterial air embolism. The venous sinus is easier to open in hysteroscopic surgery. Embolism will occur when a pressure gradient is formed between the air entering site and the right atrium, the air will enter the vein from this site due to the pressure. Its mechanism is diverse, which is closely related to

the surgical site, bubble size, bubble solubility, operating instruments and other factors. It is easier for air to enter the blood vessels if the surgical site is above the level of the heart. Each diastolic period of the heart will produce negative pressure in the venous system, making bubbles reach the right side of the heart. These bubbles remain in the right ventricular and pulmonary circulation while larger bubbles lead to cardiovascular failure and smaller bubbles stay downstream of the pulmonary circulation, producing areas of ventilation perfusion mismatch according to their relative size, which may lead to clinically significant changes in the patient's hemodynamics and respiratory status [1]. Relevant studies have reported that the lethal dose of air in adults is estimated to be between 200 and 300 mL (3-5 mL/kg) [2]. In essence, the closer the air inlet is to the right heart, the less air is required to cause fatal consequences. Intravascular gas can not only cause arterial obstruction, but also damage endothelium, secondary vasospasm, capillary leakage and activate inflammatory system [3]. The solubility of nitrogen in blood is much lower than that of carbon dioxide or oxygen in the environment, so it has greater bubble forming ability. The embolism formed by nitrogen is often more serious, but carbon dioxide embolism is usually less dangerous than indoor air embolism while carbon dioxide is more soluble in blood than air [4].

3. Clinical Manifestations

The severity of clinical symptoms is related to the location of air embolism, the solubility of blood, the volume of gas entering the human body and the rate of gas accumulation. The clinical manifestations will vary according to the affected vessels, but the manifestations of the cardiovascular, pulmonary and nervous systems are more clinically significant because these systems are highly vulnerable to hypoxia. It may be the symptoms of air embolism if the patient has chest pain, dyspnea, headache and blurred consciousness during the operation. In addition, it can lead to myocardial ischemia, arrhythmia, hypotension and cardiac arrest if the embolism is serious, and patients may have vague consciousness, seizures, transient ischemic attack and stroke if cerebral artery embolism occurs. When air enters the left ventricle and aorta, it can block any peripheral artery and cause ischemia. George A. vilos et al [5] reported 5 cases of hysteroscopic surgery. It was found that 5 patients had the same ventilation and hemodynamic decompensation symptoms during hysteroscopic surgery, including sudden decrease of end expiratory carbon dioxide and decrease of oxygen saturation. All patients returned to normal after stopping surgery and resuscitation. In 2016, Cédric van dijck et al [6] analyzed 7 cases of air embolism under hysteroscopy and found that the clinical characteristics of air embolism included decreased $ETCO_2$ (all cases), decreased blood pressure (3 cases), decreased SpO_2 (2 cases) and increased heart rate (2 cases). One patient reported ST segment changes of II, III and AVF. Boohwi Hong [7] reported that when a 57 year old postmenopausal woman underwent hysteroscopic surgery, the blood oxygen saturation suddenly decreased from 100% to 97%, the end tidal carbon dioxide ($ETCO_2$) decreased from 35 mm Hg to 27mm Hg, and the blood pressure decreased from 122 mm Hg / 72 mm Hg to 87 mm Hg / 49mm Hg. The ECG began to show the low ST segment pressure of lead II. Focused echocardiography was performed in the operating room, although there was no right ventricular dysfunction (right ventricular enlargement or left ventricular D-shape), Hbubbles can be seen in the right atrium and right ventricle, as well as in the left atrium and left ventricle. Colin J. McCarthy et al [8] analyzed 67 cases of air embolism, including 36 cases of air embolism in the right heart or pulmonary artery, 21 cases of cerebral embolism, and other cases involving limbs or coronary arteries. Air embolism can cause acute myocardial infarction, cardiac arrest, hypotension, decrease of blood oxygen saturation, neurological symptoms, seizures, cyanosis and decrease of end respiratory carbon dioxide. Among them, 13 patients had cardiac arrest immediately, though in a few cases, the patients were found to be completely asymptomatic.

4. Auxiliary Inspection

The occurrence and progress of air embolism is very rapid, so medical personnel need to be highly vigilant. When patients have sudden cardiovascular or nervous system symptoms during surgery, we should attach great attention to them. At present, it mainly depends on the clinical manifestations during the operation or the imaging examination after the operation. In order to improve the diagnostic rate, sensitive and noninvasive monitoring equipment should be used. The selection of monitoring device should be determined according to the operation, the location of patients, the professional knowledge of anesthesiologists using the device and the overall medical condition of patients [9].

1. Echocardiography

At present, transesophageal echocardiography (TEE) is considered as the gold standard for detection. This instrument is the most sensitive monitoring device for air embolism, which can detect 0.02 mL/kg air [10]. TEE is a hemodynamic monitoring method and a powerful diagnostic tool. It enables anesthesiologists to visualize the structural anatomy of the heart and large blood vessels, and monitor the hemodynamics and function of the cardiovascular system. The direct and rapid visualization of anatomical structure greatly improves the quality of surgical decision-making. For anesthesiologists, it is more important to evaluate the cardiac function of transesophageal echocardiography, because it has become essential for better intraoperative management. When air exists in the human body, anesthesiologists can be reminded to take relevant measures as soon as possible to prevent more serious consequences [11]. It can detect not only large venous emboli and microemboli, but also contradictory arterial emboli that may lead to ischemic brain complications. Simon T. SchäFe et al [12] Proved through animal experiments that intracardiac echocardiography is more sensitive than

transesophageal echocardiography in detecting small air embolism. However, due to the limitations of the current research, it needs further research. Transthoracic echocardiography is a powerful noninvasive diagnostic, monitoring and measuring equipment, and its noninvasive can be widely used in clinic. Jingjing Ji et al [13] reported 9 cases of air embolism, of which 7 cases were diagnosed as air embolism by transthoracic echocardiography (TTE). All cases recovered smoothly under TTE and combined treatment, except 1 case of neurosurgical patient died of postoperative hemorrhagic stroke. Studies have shown that transesophageal echocardiography is a promising tool to help diagnose perioperative venous air embolism, especially in evaluating the causes of concurrent intracardiac defects, circulatory failure and improving the prognosis of patients.

2. end-tidal carbon dioxide ($ETCO_2$)

The decrease of end expiratory CO_2 partial pressure is an early sign of air embolism. It is a popular, moderately sensitive, semi-quantitative, easy-to-use, noninvasive and relatively cheap monitoring technology. M. P. pandia et al [14] analyzed the anesthesia records of 63 surgical patients. In all patients in $ETCO_2$ negative group, the diagnosis of venous air embolism is based on the evidence of bubbles on tee monitor, while in $ETCO_2$ positive group, TEE and $ETCO_2$ have evidence of air embolism. This suggests that CO_2 measurement is a very effective monitoring technique for detecting all venous air embolism serious enough to cause significant hemodynamic disorders. Xu Yunqiao [15] and others included 300 patients who underwent hysteroscopic surgery, of which 34 patients had air embolism. Relevant indexes were detected during operation. The study showed that there were continuous groups of air embolism signals in the right atrium, and the decrease of $ETCO_2$ was greater than 5 mm Hg, indicating that air embolism may occur.

Therefore, anesthesiologists need to be highly vigilant in the process of anesthesia to predict the occurrence of air embolism in time [17]. Anesthesiologists should pay attention to the changes of blood oxygen saturation, end expiratory carbon dioxide, blood pressure and heart rhythm, so as to take relevant measures in time when air embolism occurs.

5. Treatment

1. Adjust the patient's position

Once air embolism is suspected during operation, the operation should be continued and completed as soon as possible for patients with stable vital signs. For patients with unstable vital signs, the medical staff should immediately suspend the operation and let the patients take a suitable position to make their right ventricle higher. The patient should be in the trenderenburg and left decubitus positions. The purpose is to trap air in the right atrium and ventricle, so as to minimize the entry of air embolism into the right ventricular outflow tract and pulmonary artery. This operation can not only prevent the embolism from flowing to the head, but also keep the blood of the left ventricle away from the coronary artery orifice and prevent myocardial infarction [19].

2. Suction gas

If the symptoms are still not improved, some bubbles can be directly pumped through the catheter to alleviate the symptoms. Yew KL et al [20] reported that intracoronary suction device can be used for the treatment of coronary air embolism. This operation can be implemented in theory, but due to the limitations of clinical practice, it has not been effectively clinically verified and needs further verification.

3. Hemodynamic support

If it is suspected that the blood volume is low, the medical staff can take intravenous infusion to the patient to increase the central venous pressure, and use positive inotropic drugs and vasopressor drugs as needed to maintain the perfusion of important organs. When patients have low blood pressure, severe bradycardia or even cardiac arrest, hemodynamic support is very important.

4. Cardiopulmonary resuscitation

Depending on the severity of the patient's symptoms, cardiopulmonary resuscitation may be required. If applicable, try to directly aspirate and remove bubbles through an available central venous catheter, and cardiopulmonary resuscitation can be performed if necessary. The basic principle of closed chest compression is to force air from the pulmonary outflow tract into the smaller pulmonary vessels, so as to improve the positive blood flow, reduce the volume of embolism, and restore the heartbeat.

5. Hyperbaric oxygen therapy

High flow of oxygen should be initiated to help reduce ischemia and accelerate the reduction in bubble size. If possible, hyperbaric oxygen therapy should be provided. Compared with indoor air, 100% oxygen is recommended, because oxygen in the blood is more soluble than nitrogen, and saturated oxygen in the blood helps to replace the nitrogen in the air embolus, which can reduce the size of bubbles in blood vessels and increase bubble solubility [19]. Although hyperbaric oxygen therapy is not a first-line treatment, it can also be a useful adjuvant treatment in severe cases to reduce the entry of air into the right ventricular outflow tract [21-22]. Literature [23] reported that a patient inadvertently received intravenous infusion of 150 mL of air, resulting in severe air embolism. After receiving hyperbaric oxygen therapy, he recovered well without adverse events, The results show that it is very important to consider the application of high flow oxygen in patients with venous embolism. Although hyperbaric oxygen therapy has not been widely used at present, it is hopeful to become a first-line treatment in the future.

6. Prevention

For the air embolism during hysteroscopy, most of the air comes from the water injection pipe. When the uterine distention fluid is used up and cannot be replaced timely, the gas will enter the uterine cavity under pressure. Chen Caiyang et al [16] proposed that multiple bottles of uterine

distention fluid can be connected with connecting tubes, which can reduce the hidden danger of air embolism. When multiple bottles of uterine distention fluid are connected, the operator should pay more attention to the total amount to prevent water poisoning. In addition, clinical studies have shown that [18] the application of uterine blocker in hysteroscopic surgery can reduce the leakage of uterine distention fluid from the cervix and block the entry of air to a certain extent, which can not only reduce the operation time, but also reduce the occurrence of air embolism to a certain extent.

7. Summary

Air embolism is a rare complication in hysteroscopic surgery, which may have terrible consequences. It is especially easy to occur in operations requiring massive inflatable compression. Therefore, hysteroscopic surgery requires the cooperation of anesthesiologists, surgeons and nursing staff. They should always be vigilant during the operation, closely observe the symptoms and signs of patients, and detect relevant indicators at the same time, so as to detect abnormalities as early as possible and prevent the occurrence of air embolism. In case of air embolism, medical staff should take relevant measures in time to prevent further deterioration of the disease.

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