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Carbon Dioxide Embolism During Laparoscopic Right Hepatectomy: A Case Report

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Abstract

Complications of laparoscopic surgery include carbon dioxide (CO_2) embolism, primarily caused by the entry of CO_2 gas into blood vessels or solid organs. If significant clinical symptoms occur, timely intervention is crucial as it can be life-threatening. We report a case of CO_2 embolism during laparoscopic right hepatectomy. The patient was a 37-year-old male with no history of liver or kidney dysfunction. During the procedure, there were two episodes of oxygen desaturation (SpO_2), and the second episode was accompanied by a significant drop in blood pressure and an increase in heart rate. However, there was no sudden decrease in the end-tidal CO_2 partial pressure ($ETCO_2$). Simultaneously, a grinding murmur was auscultated in the precordial area, and foamy blood was aspirated from the right internal jugular vein catheter. This article describes a case of CO_2 embolism during laparoscopic surgery and provides a summary of its causes, clinical manifestations, diagnosis, and treatment. It is hoped that this article will contribute to the timely recognition and management of such cases, thereby preventing any potential adverse outcomes for patients.

Keywords

Carbon Dioxide, Embolism, Laparoscopy, Hepatectomy, Case Report

Introduction

Laparoscopic liver resection has become a popular approach for minimizing intraoperative bleeding, reducing incision size, and promoting rapid patient recovery. It involves establishing pneumoperitoneum using CO_2 gas [1]. Laparoscopic liver resection requires low central venous pressure, high intra-abdominal pressure, and specific patient positioning [2]. Additionally, due to the rich and complex vascular structure of the liver, CO_2 embolism can occur. Severe CO_2 embolism can lead to risks such as hypotension, hypoxia, neurological events, arrhythmias, and even cardiac arrest, with a mortality rate as high as 28% [3]. Therefore, timely detection, accurate diagnosis, and appropriate management are crucial.

Here, we report a case of carbon dioxide embolism during laparoscopic right hepatectomy. The primary manifestations included a decrease in SpO_2 accompanied by a drop in blood pressure and an increase in heart rate, while $ETCO_2$ did not exhibit a sudden decrease. We promptly made the diagnosis and initiated appropriate management.

Case Report

The patient is a 37-year-old male with a height of

Case Report

163cm and weight of 52kg who was admitted due to intermittent abdominal pain for 1 month. The patient has generally been in good health and had previously undergone left hemihepatectomy in 2018 for a liver hydatid cyst. Preoperative electrocardiogram, routine blood tests, biochemical tests, and coagulation function showed no significant abnormalities. The hydatid cyst IgG antibody test was positive. An abdominal CT scan revealed multiple heterogeneous low-density lesions in the liver, with the largest lesion located in the right lobe measuring approximately 8.10*7.77cm (**Fig-1**) in maximum cross-section, showing scattered dot-like and streak-like high-density shadows.

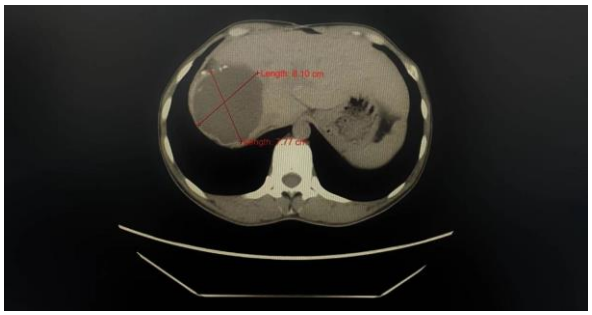

Fig-1:

*The Abdominal CT Scan Showed a Large Lesion in the Right Lobe Measuring approximately 8.10*7.77cm.*

The patient was undergoing laparoscopic right hemihepatectomy. Upon admission, the patient was conscious. An intravenous infusion of lactated Ringer's solution (500 ml) was initiated through an open venous access. The electrocardiogram monitoring showed a heart rate of 78 beats per minute, blood pressure of 141/78mmHg, respiratory rate of 15 breaths per minute, and SpO_2 of 96%. Anesthesia induction was performed by sequential intravenous administration of 2mg midazolam, 17.5μg sufentanil, 12mg Cisatracurium, and 60 mg propofol. After satisfactory muscle relaxation, a size 7.5 regular endotracheal tube was placed orally under direct laryngoscopy, with the tube tip positioned 22 cm from the incisors. Bilateral lung auscultation revealed symmetrical breath sounds. Volume-controlled ventilation was initiated, with an airway pressure of 15cmH_2O and an $ETCO_2$ of 36mmHg. Radial artery cannulation was performed for invasive blood pressure monitoring, and deep venous cannulation was performed on the right internal jugular vein.

The patient was placed in the reverse Trendelenburg position with the legs apart. Surgery commenced with establishing pneumoperitoneum, with an intraabdominal pressure set at 15mmHg and a flow rate of 8 L/min. Approximately 5 minutes after the start of surgery, the SpO_2 gradually decreased from 100% to 95%. No significant abnormalities were observed in blood pressure, heart rate, airway pressure, or $ETCO_2$. After excluding anesthesia machine and gas supply malfunctions, endotracheal tube kinking, and other factors, the ventilation was switched to pure oxygen ventilation. After increasing positive end-expiratory pressure, the SpO_2 returned to 100%. Arterial blood gas analysis showed a pH of 7.397, a partial pressure of oxygen (PaO_2) of 225.5mmHg, a partial pressure of carbon dioxide ($PaCO_2$) of 38.6mmHg, and a base excess (BE) of 1.81. Following consultation with the surgical team, the pneumoperitoneum pressure was reduced to 13mmHg.

Around 50 minutes after the start of surgery, the SpO_2 began to decrease slowly again. The monitoring equipment and anesthesia machine were found to be functioning properly, and the depth of the endotracheal tube remained unchanged. At this time, the blood pressure was 85/51mmHg, heart rate was 117 beats per minute, SpO_2 was 82%, $ETCO_2$ was 47mmHg, and airway pressure increased to 25cmH_2O. Auscultation revealed significantly diminished breath sounds in both lungs, and a grinding murmur was heard in the precordial area. There was palpable crepitus in the anterior chest. The surgical team reported that they were dissecting the hepatic vein, and there was a breach in the hepatic vein. Arterial

Fig-2: Foamy Blood were drawn out the Right Internal Jugular Vein Cenrtal Line.

blood gas analysis showed a pH of 7.115, a PaO_2 of 81.7mmHg, a $PaCO_2$ of 68.5mmHg, and a BE of -1.9. A high suspicion of CO_2 embolism was raised, and foamy blood was aspirated from the right internal jugular vein central line (**Fig-2**).

The surgery was immediately paused, and pneumoperitoneum was discontinued. The patient's position was changed to a head-down left lateral position, and pure oxygen ventilation was initiated. Positive end-expiratory pressure (PEEP) of 5cmH_2O was applied, the fluid infusion rate was increased, and hydroxylamine was administered intravenously to increase blood pressure. The blood pressure increased to 102/61mmHg, SpO_2 returned to 100%, $ETCO_2$ increased to 47mmHg, and breath sounds were significantly amplified upon lung auscultation. Hemodynamic monitoring using pulse index continuous cardiac output (PICCO) was initiated. After the patient's circulation stabilized, the surgery was resumed through an open approach. The procedure was completed successfully with an estimated blood loss of approximately 600ml (**Fig-3**).

Fig-3: Large Lesion Removed from the Right Lobe.

Postoperative arterial blood gas analysis showed a pH of 7.321, a PaO_2 of 192.4mmHg, a $PaCO_2$ of 41.6mmHg, and a BE of -1 (**Table-1**). The oral secretions were thoroughly cleared, and the endotracheal tube was removed after the patient regained normal spontaneous breathing and consciousness. The patient was then transferred to the post-anesthesia care unit (PACU). On the third day after the surgery, the patient's vital signs were stable, and the patient was in good spirits. Lung auscultation revealed clear breath sounds without any adventitious sounds.

Table-1: The Arterial Blood Gas Analysis During Operation

Time	The first decrease of SpO_2	The second decrease of SpO_2	End of operation
PH	7.397	7.115	7.321
PaO_2 (mmHg)	225.5	81.7	192.4
PCO_2 (mmHg)	38.6	68.5	41.6
BE (mmol/L)	1.81	-1.9	-1

Discussion

Laparoscopy is widely used in surgical procedures due to its advantages of minimal invasiveness and rapid recovery. To facilitate the operation, ensure clear visualization, and avoid damage to abdominal organs, pneumoperitoneum is created by insufflating gas into the abdominal cavity. Carbon dioxide, which is colorless, odorless, non-flammable, and highly soluble in blood, is commonly used for establishing artificial pneumoperitoneum [4]. However, CO_2 embolism is a rare complication specific to laparoscopy. The severity of gas embolism depends on the type and volume of gas as well as the rate of gas entry into the vasculature [5,6]. In most cases, CO_2 embolism does not present with clinical symptoms due to the high solubility of CO_2. However, symptomatic CO_2 embolism is uncommon, and if not promptly diagnosed and managed correctly, it can lead to serious consequences [7].

Under conditions of high intraabdominal pressure, CO_2 can enter ruptured blood vessels and subsequently obstruct the right atrium, resulting in decreased cardiac output and systemic hypotension. Some gas emboli may also enter the pulmonary circulation, causing pulmonary hypertension and pulmonary edema [8,9]. During general anesthesia, CO_2 embolism is characterized by hypotension, tachycardia, hypoxemia, hypercapnia, increased airway pressure, and elevated central venous pressure, which can lead to arrhythmias or even cardiac arrest [10]. $ETCO_2$ abruptly decreases in most cases. The hepatic veins, including the left and right hepatic veins and their tributaries, are prone to air embolism due to their

large lumens, thin walls, numerous branches, susceptibility to tearing, and lack of valvular blood reflux. Laparoscopic liver resection, which requires low central venous pressure and high pneumoperitoneum pressure, increases the risk of gas embolism.

Prompt and accurate identification of the aforementioned clinical symptoms is crucial. Studies have indicated that the lethal dose of air entering the bloodstream in adult's ranges from 3 to 5 ml/kg [7]. $ETCO_2$ is a convenient, non-invasive, and sensitive indicator of gas embolism, capable of detecting as little as 0.5 milliliters per kilogram of gas entering the circulation [11]. A sudden decrease in $ETCO_2$ may serve as an important early sign of carbon dioxide embolism, with studies showing it to have a sensitivity of up to 87% [12]. $ETCO_2$ measures the partial pressure or concentration of carbon dioxide in the mixed alveolar gas exhaled at the end of expiration, which is commonly used to assess a patient's ventilation, circulatory function, and pulmonary blood flow. When gas enters the venous system and accumulates in the pulmonary artery, it causes a decrease in the ventilation-perfusion ratio, increases physiological dead space, and dilutes the concentration of exhaled carbon dioxide at the end of expiration. Hence, a sudden decrease in $PETCO_2$ is observed [13]. However, in some cases of carbon dioxide embolism, a short rise in $ETCO_2$ may result from the absorption of a large amount of carbon dioxide in the bloodstream, leading to higher $PaCO_2$ levels [14,15]. Therefore, further analysis should be combined with arterial blood gas measurements.

TEE is the most sensitive method for monitoring CO_2 embolism, capable of detecting air volumes as small as 0.02 ml/kg [16]. TEE can detect the occurrence of gas embolism earlier than clinical changes and provides real-time monitoring of gas embolism. In a study of laparoscopic cholecystectomy, CO_2 embolism was detected via TEE in 69% of patients [17]. Secretain et al. developed a software algorithm using transesophageal echocardiography to identify and measure potential emboli during cardiac surgery [18]. When symptomatic CO_2 embolism occurs, prompt management is crucial. First, pneumoperitoneum should be immediately discontinued, and the patient's position should be changed to a head-down left lateral position to prevent air emboli from entering the pulmonary arteries and the head. Concurrently, pure oxygen ventilation should be initiated to eliminate CO_2 and improve hypoxemia. Increasing positive end-expiratory pressure ventilation, rapidly infusing fluids to raise central venous pressure, using vasopressor medications to maintain hemodynamic stability, and actively performing chest compressions in cases of cardiac arrest can effectively break down large gas emboli into smaller ones. Some patients may have gas extracted from central venous catheters, and a grinding murmur may be auscultated in the precordial area [15].

In this case, a young male patient with a history of liver hydatid cyst excision was scheduled to undergo laparoscopic right hemihepatectomy. Although there was no sudden decrease in $ETCO_2$, the surgical team observed a breach in the hepatic vein based on clinical presentation and blood gas analysis. Additionally, foamy blood was aspirated from the central venous catheter. Therefore, CO_2 embolism was suspected, and prompt management led to a good prognosis for the patient. However, due to the urgent situation, TEE examination was not performed.

In conclusion, although symptomatic CO_2 embolism during laparoscopy is rare, its potential harm should not be overlooked. Studies have indicated that risk factors for CO_2 embolism include high pneumoperitoneum pressure, previous abdominal or pelvic surgery, and intraoperative venous injury. It is important not to rely solely on a decrease in $ETCO_2$ for diagnosis but to consider other clinical manifestations. TEE can be performed in critically ill or high-risk patients. Furthermore, in a randomized trial involving 498 patients undergoing laparoscopic surgery, the incidence of CO_2 embolism was significantly higher in the high pneumoperitoneum pressure group (15 mmHg CO_2) compared to the low-insufflation group (12 mmHg CO_2) [19,20]. Therefore, appropriate pneumoperitoneum pressure is an important measure for preventing CO_2 embolism. Early identification, diagnosis, intervention, and effective prevention are essential when CO_2 embolism occurs.

Conclusion

Laparoscopic surgery is becoming increasingly widespread, and the complication of CO_2 embolism cannot be ignored. When significant clinical symptoms occur, prompt identification and appropriate management are crucial. Surgeons and anesthesiologists should actively communicate throughout the surgical procedure, setting appropriate pneumoperitoneum pressure. Anesthesiologists should closely monitor the patient's hemodynamic changes to detect any early signs of CO_2 embolism.

In situations where feasible, routine transesophageal echocardiography (TEE) monitoring can be performed in critically ill patients or those with large intra-abdominal masses. TEE provides real-time monitoring and can help in the early detection of gas embolism, contributing to better patient outcomes.

By adhering to these practices and remaining vigilant during laparoscopic procedures, healthcare professionals can reduce the risk of CO_2 embolism and ensure the safety and well-being of patients undergoing such surgeries.

Conflict of Interest

The author has read and approved the final version of the manuscript. The author has no conflicts of interest to declare.

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