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Introduction

Laparoscopy is deemed a “minimally” invasive procedure that allows for exploration through an endoscope of the peritoneal cavity after insufflation of carbon dioxide (CO2) [1]. It has been widely used during many types of surgery. There are a number of advantages compared to open procedure which includes: decreased risk of bleeding, infection, and postoperative pain [2]. However, there are also some complications associated with laparoscopic surgery. For example, the pneumoperitoneum may lead to decreased cardiac output and/or increased systemic vascular resistance. In addition, the Carbon dioxide pneumoperitoneum may cause respiratory acidosis and deep venous thrombosis [3].

Although CO2 embolisms are rare, they are potentially fatal if they are not diagnosed or treated immediately. This is especially true when the CO2 from the right heart flows into the left heart [4]. Clinically, carbon dioxide embolism can present itself with systemic hypotension, dyspnea, cyanosis, tachycardia or bradycardia, arrhythmia or asystole, elevated pulmonary arterial pressure(PAP), elevated central venous pressure, hypoxemia and increased arterial partial pressure of carbon dioxide, increase or decrease end-tidal carbon dioxide tension [5]. There are case reports about cardiac arrest associated with CO2 embolism during laparoscopic surgery [6]. We are reporting this case of potentially fatal complication of massive CO2 embolism during laparoscopy adrenalectomy at our institute. Even the patient had experienced a massive CO2 embolism during the surgery, he discharged without any complication by the twelfth day after the operation.

Case Report

A 65-year-old man, with suspected right adrenal metastasis from hepatic carcinoma, was scheduled to undergo a laparoscopic right adrenalectomy. About 75 minutes into the operation, when attempting to remove the adrenal gland that was tightly adhesive to the inferior vena cava (IVC), the surgeon accidently nicked the inferior vena cava which resulted in a large tear of about 2 x 2 cm. Considering the difficulty of performing exploratory laparotomy due to previous hepatic tumor excision related intra-abdominal adhesion, the surgeon tried to sow the torn IVC through the use of the laparoscope and to control the bleeding via carbon dioxide (CO2) insufflation pressure. This resulted in a massive amount of gas entering the vessel via the IVC broken hole. When we performed a transesophageal echocardiography (TEE), it was revealed that the right atrium and right ventricle were totally white out because they were full of air. About 20 minutes after the IVC tear, the TEE image also revealed that the left heart also contained scattered air embolisms. The surgeon spent about 60 minutes on repairing the IVC tear. Blood pressure was stable during the IVC tear insult but dropped slightly after the IVC tear repaired. Low dose norepinephrine and dopamine continuous infusion were administered to stabilize the patient’s blood pressure. After the operation, the patient presented mild weakness in his left limbs. Fortunately, the symptoms dissipated two days after the surgery. 12 days later, the patient was discharged without any neurologic sequelae.
The patient was positioned in a left lateral recumbent position. An additional 50 μg fentanyl was administered while the Veress needle was introduced. During the surgery, we began with a high flow of CO2 intra-peritoneal insufflation to achieve an intra-abdominal pressure of 15 mmHg.

During the initial 75 minutes, the patient’s vital signs were stable and the procedure was performed smoothly. However, when attempting to remove the adrenal gland and adrenal tumor which was tightly adhered to the IVC, the surgeon accidentally nicked the large inferior vena cava which resulted in a large IVC tear of about 2 x 2 cm. The bleeding from the torn IVC was temporary compressed by the guaze. However we suspect that a massive amount of CO2 entered the vessel via the IVC broken hole. Taking into account the difficulty of performing exploratory laparotomy due to previous hepatic tumor excision related intra-abdominal adhesion, the surgeon tried to sow the torn IVC by the use of laparoscope and to control the bleeding via carbon dioxide (CO2) insufflation pressure. However we suspect that a massive amount of CO2 entered the vessel via the IVC broken hole while the surgeon sow the torn IVC. They spent about 60 minutes on repairing the IVC tear. Blood pressure was stable during the IVC tear insult but dropped slightly after the torn IVC repaired. Systolic blood pressure during the insult was kept at 100–130 mmHg, pulse 70–90/min, airway pressure was maintained at 35 mmHg which may be induced by the laparoscope and SPO2% was 100%. However, the end tidal CO2 gradually elevated from 35 mmHg to 53 mmHg. The ventilator respiratory rate was then set higher to wash out CO2. The blood gas 3 hours after the insult showed PH 7.1, PCO2 82.9%, PO2 186% (FiO2 85%), SaO2 99%. Post-surgery, the patient was transferred to the ICU with mechanical ventilation to receive further care.

During the ICU admission, the ECG showed SiQ3 without ST-T change. Acute respiratory distress syndrome (ARDS) was also diagnosed via chest radiography and clinical presentation. Low dose norepinephrine and dopamine continuous infusion were administered for SIRS reaction but were then gradually tapered off in 2 days. Neurological examinations showed mild weakness with muscle power of 4+ in the patient’s left limbs during the first day after the surgery but these symptoms dissipated by the second day after the operation. By the second day the patient was under a stable enough condition to be extubated and transferred out of the ICU into the general ward.

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Table 1: preoperative base situation of this patient

| The patient’s base situation |                     |
|-----------------------------|---------------------|
| Height/weight               | 167cm/ 67kg         |
| Resting blood pressure      | 112/64 mmHg         |
| pulse                       | 86/min;             |
| SaO2%                       | on room air 99%     |

Figure 1: TEE four chamber view. RA and RV were full of air (CO2), totally white out, persisted for 60 minutes. RA: right atrium; RV: right ventricle; LA: left atrium; LV: left ventricle.

Figure 2: TEE long axis view. CO2 emboli can be found even in the ascending aorta. LA: left atrium; AO: ascending aorta.

The patient was under a stable enough condition to be extubated and transferred out of the ICU into the general ward.
by the fifth day. He was discharged by the twelfth day after the surgery without any residual complication.

**Discussion**

Carbon dioxide is the most widely used insufflation gas. Most serious cases of CO2 embolism reported in the literature occurs during the beginning of the procedure, usually due to the misplacement of the Veress needle either directly into a vein or parenchymal organ. Lesser amounts of CO2 may also enter circulation through openings in injured vessels, as seen in our case, which explains the late onset of the carbon dioxide embolisms.

Rapid entrainment of a large volume of gas can lead to the formation of large emboli, which may lodge in a large central vessel and potentially lead to cardiovascular collapse [7]. In our case, the surgeon was facing the dilemma of whether to transform into open surgery. Considering previous hepatic tumor excision related intra-abdominal adhesion, exploratory laparotomy to approach the bleeder would be also difficult. Instead, we tried an adventurous method: we controlled the IVC bleeding via the carbon dioxide (CO2) insufflation pressure, at the same time, the surgeon saw the torn IVC by the use of laparoscope. A necessary condition for the development of gas embolism is the presence of an open vein with a lower pressure in the vein than the surrounding pressure [8]. Nevertheless, it is because the little higher pressure of the CO2 gas insufflation, the bleeding rate was not so fast to be life-threatening. But the pressure of CO2 gas insufflation can’t be too high to make fatal amount of CO2 embolism.

Fortunately, our patient did not develop cardiovascular collapse even encounter this massive CO2 embolism. It may because the slow entrainment of the CO2 and the high solubility of CO2 (20:1 to oxygen and 25:1 to nitrogen) [4]. Mayer et al. [9], described a mortality of 60% at a continuous intravenous CO2 infusion rate of 1.2 mL/kg/min, which is equivalent to a rate of 72 mL/min for a 60 kg person. That volume is only 5% of the volume of carbon dioxide that may be infused into a vein, intentionally cannulated by a Veress needle, in one minute at a low-flow rate.9 Our effort to keep the balance of IVC venous pressure and surrounding CO2 insufflation pressure during the episode may prevent a massive fatal CO2 embolism and a fatal bleeding rate. About 20 minutes after IVC tear, the TEE image also revealed scattered air embolisms in the left heart. The foramen ovale didn’t open on the TEE image. We suspect that the left heart gas emboli may have been caused from pulmonary capillary diffusion when large amounts of air entered the vena cava. Post-surgery, the patient developed neurologic signs of left limbs weakness but was able to rapidly recover in 2 days. The rapid improvement maybe attributed to the high solubility of CO2.

Treatment of CO2 embolisms consists of the immediate cessation of insufflation and the release of the pneumoperitoneum, steep head-down and left lateral decubitus position. And the discontinuation of nitrous oxide and to ventilate with 100% oxygen. In addition, adequate hydration and the placement of a CVC to aspirate CO2 is required. Our patient was already in the head-down and left lateral decubitus position as it was required for surgery. However, the insufflation of CO2 didn’t cease in our patient, because the surgeon needed to control the bleeding through applying pneumoperitoneum pressure.

In conclusion, our patient’s prognosis was good despite having gone through a massive CO2 embolism event. The patient’s relatively stable vital signs and possibly intra-abdominal adhesion were the reasons why we did not transfer the laparoscope to exploratory laparotomy nor immediately cease CO2 insufflation. In addition, the rapid improvement from the neurological symptoms maybe attribute to the high solubility of CO2. Hence, we hypothesize that the decision of whether to cease the pneumoperitoneum immediately when CO2 embolisms occur, may depend on the patient’s hemodynamics. In admission, it is important to find the balance between venous and CO2 insufflation pressure to avoid massive bleeding or fatal amount of CO2 embolisms. And that the neurological tolerance of CO2 emboli may be much higher than that of other gases.

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