Paradoxical Carbon Dioxide Embolism During Pneumoperitoneum in Laparoscopic Surgery for a Huge Renal Angiomyolipoma

Yu-Yin Huang[1,2], Hsin-Lun Wu[2,3], Mei-Yung Tsou[2,3], Hsiao-Jen Zong[2,4], Wan-You Guo[2,5], Kwok-Hon Chan[2,3], Chien-Kun Ting[2,3]*

[1]Department of Anesthesiology, Cheng-Hsin Rehabilitation Medical Center, [2]National Yang-Ming University School of Medicine, and Departments of [3]Anesthesiology, [4]Urology and [5]Radiology, Taipei Veterans General Hospital, Taipei, Taiwan, R.O.C.

We present a case of paradoxical gas embolism during CO_2 insufflation in laparoscopic nephrectomy for a huge renal angiomyolipoma. Paradoxical CO_2 embolism in the left heart chambers without demonstrable intracardiac right-to-left shunt was detected by transesophageal echocardiography (TEE). The surgical procedure was stopped immediately, but the patient recovered with mild neurologic deficit. We speculate that rapid pneumoperitoneum introduction pushed CO_2 into the abnormal vasculature of the angiomyolipoma, which communicates with the systemic vascular system, causing pseudoaneurysm formation. Follow-up abdominal computed tomography showed a new pseudoaneurysm inside the tumor. If intracardiac right-to-left shunt is excluded for the reason of paradoxical gas existence, there remains extracardiac right-to-left shunt, with transpulmonary passage of the venous emboli being the most likely mechanism. In fact, the cause of paradoxical gas embolism in this case remains unknown. Therefore, laparoscopic surgery for huge angiomyolipoma should be performed with extreme caution; an open procedure may be considered as an alternative. [*J Chin Med Assoc* 2008;71(4):214–217]

Key Words: angiomyolipoma, paradoxical gas embolism, transesophageal echocardiography

Introduction

Venous carbon dioxide (CO_2) embolism is a recognized risk during laparoscopic procedures. Its clinical presentation ranges from asymptomatic to neurologic injury, cardiovascular collapse or even death depending on the rate and volume of gas entrapment and patient condition. Venous CO_2 embolism is a life-threatening complication of laparoscopy, occurring in 15 per 100,000 cases per year. The mechanism may be inadvertent venous cannulation or absorption through open venous channels, which usually happens in the first 5–8 minutes after the start of CO_2 insufflation.[1,2] Paradoxical CO_2 embolism is an extremely rare event but can result in disastrous and fatal consequences.[3] The cause has been suggested to be intracardiac or extracardiac right-to-left shunting of venous gas embolism. We describe a case of paradoxical CO_2 embolism during CO_2 insufflation in laparoscopic nephrectomy that was immediately diagnosed by transesophageal echocardiography (TEE). No evidence of demonstrable intracardiac right-to-left shunt was found, but the patient recovered with neurological deficit. The possible mechanisms for CO_2 embolism development are discussed.

Case Report

A 76-year-old woman (51 kg; 150 cm) was admitted due to a huge angiomyolipoma (11.9 × 8.6 cm) of the right kidney, confirmed by computed tomography (CT) scan, which had been causing right flank pain of several weeks' duration. Laparoscopic partial nephrectomy was

*Correspondence to: Dr Chien-Kun Ting, Department of Anesthesiology, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan, R.O.C.
E-mail: ckting@vghtpe.gov.tw • Received: March 12, 2007 • Accepted: October 5, 2007

scheduled. She had a history of type 2 diabetes mellitus and hypertension under regular medication.

Induction of general anesthesia was performed with intravenous fentanyl 150 μg, thiamylal 360 mg, rocuronium 40 mg, and esmolol 20 mg under standard monitors of EKG, noninvasive blood pressure device, pulse oximetry, and capnography. Invasive monitors included radial arterial line and central venous catheterization. After successful endotracheal tube intubation, anesthesia was maintained with isoflurane in 50% oxygen. Mechanical ventilation was adjusted to maintain end-tidal CO_2 ($EtCO_2$) between 30 and 40 mmHg.

The patient was placed in 60-degree-tilted flank position for surgical transperitoneal approach. Veress needle was then inserted at Palmer's point (2 finger breadths below the right subcostal margin and just lateral to the border of the rectus abdominis). After saline-drop test, pneumoperitoneum was developed by CO_2 insufflation at a rate of 3 L/min and intra-abdominal pressure was built up to 15 mmHg. A few minutes later, $EtCO_2$ dropped abruptly from 31 to 16 mmHg and pulse oximeter oxygen saturation (SpO_2) decreased rapidly from 100% to 76%. Meanwhile, systolic arterial blood pressure dropped suddenly from 140 to 90 mmHg, and EKG showed sinus tachycardia (100 ± 10/min) with significant ST depression, 1.5 mm maximally. Arterial blood gas showed pH 7.22, $PaCO_2$ 76.7 mmHg, and PaO_2 52.8 mmHg. There was no change in airway pressure. The surgeon was informed right away, and pneumoperitoneum was quickly released.

The patient was placed in supine Trendelenburg position and given 100% oxygen immediately. TEE was inserted and demonstrated acute gas embolism entering the right atrium and left side of the heart (Figure 1). Marked interatrial septal bulging to the left side was observed, but there was no sign of patent foramen ovale (PFO) on color-flow Doppler imaging. Paradoxical gas embolism was impressed. After deflation of pneumoperitoneum and supportive treatment, $EtCO_2$ returned to 29 mmHg and SpO_2 to 100% within about 5 minutes. Arterial blood gas revealed pH 7.32, $PaCO_2$ 47.8 mmHg, and PaO_2 269 mmHg. The heart rate returned to normal range. Meanwhile, gas bubbles in heart chambers delineated by TEE also scattered and cleared out gradually following normalization of $EtCO_2$ and SpO_2 recovery. The surgery was stopped and the patient was allowed to awake.

Two hours after discontinuation of general anesthesia, the patient awoke in the post-anesthetic care unit, but was disoriented. Her pupil size was 2 mm symmetrically with prompt light reflex. Weakness of 4 limbs and generalized myoclonus contractions were noted. Intravenous midazolam 5 mg and valproate 400 mg were given to control her symptoms. Emergent brain CT was examined but there was no obvious identifiable focal lesion. About 10 hours after the embolic episode, magnetic resonance imaging showed no evidence of acute infarction. Subsequent magnetic resonance angiography disclosed patency of all intracranial major vessels.

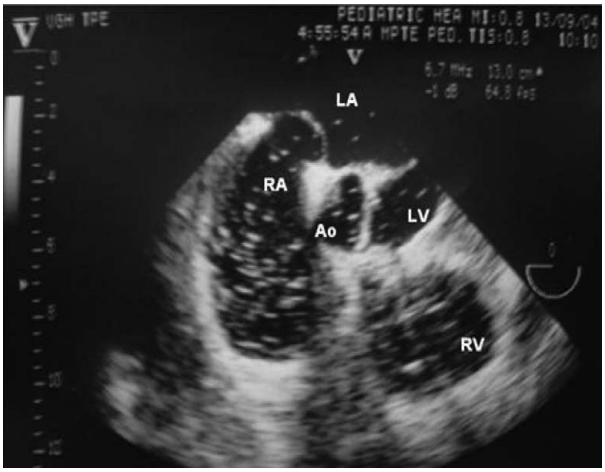

Figure 1. Intraoperative TEE shortly after the gas embolic event occurred. TEE demonstrated gas bubbles (multiple bright, mobile circular particles) in the right atrium (RA), right ventricle (RV), left atrium (LA), left ventricle (LV) and aortic root (Ao). The interatrial septum bulged remarkably to the left side.

Continuous infusion of midazolam 0.1 mg/kg/hr was used for both sedation and treatment of persistent myoclonus contractions while the patient remained endotracheally intubated with controlled ventilation. Follow-up contrast-enhanced abdominal CT showed a new pseudoaneurysm formation in the center of the tumor compared with the preoperative CT scan (Figure 2). Supportive treatment was continued for the patient.

On postoperative day 5, myoclonus ceased and midazolam was tapered gradually. Repeated TEE examination revealed no existence of PFO under provoking saline injection by the cardiologist. On postoperative day 6, her consciousness was clear but there was residual neurologic deficit of 4-limb weakness. She was discharged with regular outpatient department visits. After 6 months of intensive physical rehabilitation, she achieved nearly full recovery.

Discussion

The triad of sudden decrease in $EtCO_2$, systolic hypotension, and desaturation without change in airway pressure in this patient strongly suggested pulmonary

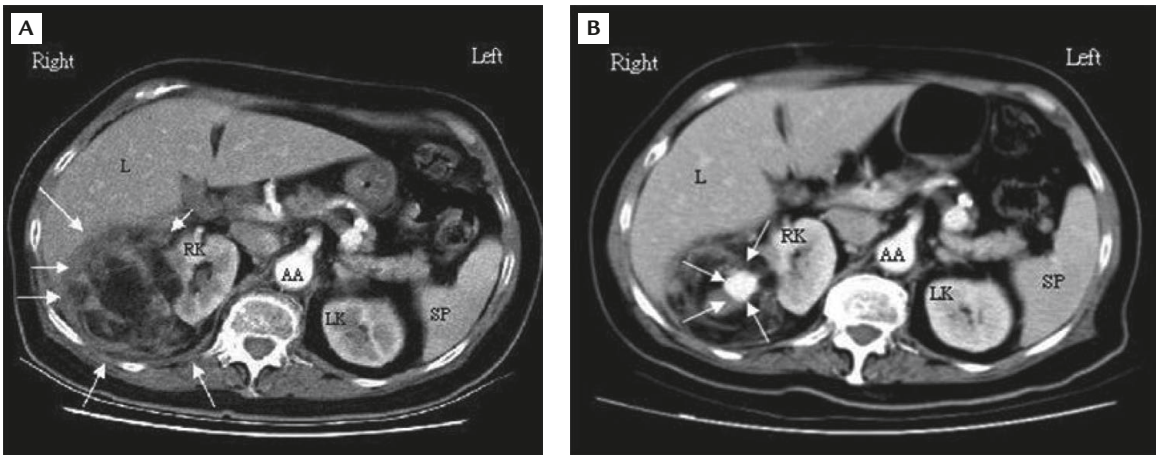

Figure 2. Contrast-enhanced abdominal CT scans before and after the episode of paradoxical CO_2 embolism. (A) Huge angiomyolipoma (arrows), measuring 11.9 × 8.6 cm, of the right kidney (RK) confined to the perirenal space. (B) Postoperatively, the same cutting level as Figure 2A shows possible pseudoaneurysm formation (arrows), enhanced brightly by contrast media, inside the tumor. LK = left kidney; SP = spleen; AA = abdominal aorta; L = liver.

CO_2 embolism.[4] Subsequent TEE examination confirmed our suspicion. However, paradoxical embolism is extremely rare and generally occurs in patients with intracardiac right-to-left shunt mostly due to PFO, which exists in about 20–30% of the general population.[5] In other situations, venous gas may enter the arterial circulation by overwhelming the mechanisms that normally prevent arterial embolism. There was no demonstrable intracardiac defect of right-to-left shunt in our patient by TEE examination both intra- and postoperatively. Therefore, we presumed that transpulmonary passage would be the likely mechanism for paradoxical embolism.

Marquez et al reported autopsy-proved cases of fatal venous embolism associated with paradoxical cerebral air embolism perioperatively without intracardiac septal defect.[6] The first real-time observation of paradoxical air embolism via transpulmonary air passage by TEE examination during suboccipital craniotomy was achieved by Bedell et al.[7] Although the lung is considered an effective physiologic filter for pulmonary gas emboli, the filtering capacity may be interfered with by an overwhelming amount of gas in the pulmonary circulation and the use of various anesthetic agents, especially volatile anesthetics.[8]

In our case, TEE was examined after the accident as a diagnostic tool. The passage of initial intracardiac gas produced by inadvertent forced CO_2 insufflation could not be observed, and a possible transient opening of PFO might be missed. If intracardiac right-to-left shunt is excluded for the reason of paradoxical gas existence, there remains extracardiac right-to-left shunt, with transpulmonary passage of the venous emboli being the most likely mechanism. In fact, the exact cause of paradoxical embolism in this case remains unknown. Fortunately, severe hemodynamic collapse did not occur in this patient. This might possibly be due to paradoxical gas release in time without formation of fatal pulmonary gas lock.

Angiomyolipoma is composed of abnormal blood vessels, smooth muscle cells, and fat. The vessels in the tumor do not have elastic fiber layer as found in normal ones and may form complex anastomosing vascular channels. Renal angiomyolipomas can sometimes invade the renal vein or extend into the vena cava, and are usually diagnosed because of their huge size and mass effect.[9] In our patient, we found a newly formed contrast-filling pocket inside the tumor on the CT scan performed after the event. The radiologic density of the pocket is parallel to that of vascular enhancement such as aorta and adjacent vascular structures. The density may suggest an abnormal communication between the pocket and vascular system. In the same cut of the CT scan before the episode, no such abnormality was seen. This interval change may imply a sudden destruction of the abnormal fragile vessels and a pseudoaneurysm or vascular pocket formation in the tumor which communicated with adjacent vascular system after the pneumoperitoneum procedure. We suppose the rapid high-flow CO_2 pneumoperitoneum induction may have pushed CO_2 through the peritoneum into the abnormal vascular channels of the tumor which anastomosed with the systemic venous system.[10,11]

In conclusion, although our patient recovered with neurologic deficit due to paradoxical gas embolism, we successfully stopped further exacerbation of the consequences by early diagnosis and management. Therefore, laparoscopic surgery for huge angiomyolipoma

should be carried out with extreme caution, or an open procedure may be considered as an alternative.

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