Case Report

Carbon dioxide gas embolism during robot-assisted laparoscopic partial nephrectomy

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Abbreviations & Acronyms
CO_2 = carbon dioxide
CT = computed tomography
$EtCO_2$ = end-tidal carbon dioxide pressure
$PaCO_2$ = partial pressure of arterial carbon dioxide
PEEP = positive end-expiratory pressure
RAPN = robot-assisted laparoscopic partial nephrectomy
RENAL score = radius, exophytic/endophytic properties of the tumor, nearness of tumor to the deepest portion of the collecting system or sinus, anterior/posterior descriptor, and the location relative to the polar line score
SpO_2 = oxygen saturation of peripheral artery
TEE = transesophageal echocardiography

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Introduction: One of the complications of laparoscopic surgery is gas embolism, which has low incidence but high mortality. Carbon dioxide embolism diagnosed during robot-assisted laparoscopic partial nephrectomy has been experienced.
Case presentation: 77-year-old woman with a left renal tumor received robot-assisted laparoscopic partial nephrectomy. End-tidal carbon dioxide pressure and oxygen saturation of peripheral artery suddenly decreased 5 min after the start of tumor resection with pneumoperitoneum pressure of 15 mmHg and positive end-expiratory pressure turned off. Therefore, pulmonary artery gas embolism was diagnosed. The pneumoperitoneum pressure was dropped, and positive end-expiratory pressure was restarted. These conditions improved and the procedure was completed.
Conclusion: Carbon dioxide gas embolism during robot-assisted partial nephrectomy should be focused on because prompt diagnosis and treatment will improve life outcomes. The optimal pneumoperitoneum pressure for each case, rather than making it uniform, should be reconsidered.

Key words: carbon dioxide embolism, end-tidal carbon dioxide pressure, laparoscopic surgery, positive end-expiratory pressure, robot-assisted laparoscopic partial nephrectomy.

Keynote message

Carbon dioxide embolism during tumor resection during robot-assisted laparoscopic partial nephrectomy has been experienced. This may be due to the excessive pneumoperitoneum pressure to the blood vessels torn on the resection surface, which should be focused during laparoscopic partial nephrectomy. Thus, excessive pneumoperitoneum pressure should be avoided and the optimal pneumoperitoneum pressure for each case, rather than making it uniform, should be reconsidered.

Introduction

CO_2 is the most common gas used for pneumoperitoneum in laparoscopic surgery. CO_2 is preferred because it is chemically inert, clear and colorless, and less combustible than air.[1] However, one of the complications of laparoscopic surgery is pulmonary artery gas embolism. In a recent meta-analysis, CO_2 embolism occurred in 7 out of 489 335 laparoscopic procedures (0.001%),[2] but the mortality rate is 28% when it occurs.[3] In this report, we present a case of gas embolism during RAPN.

Case presentation

77-year-old woman with 2-cm tumor on the left kidney (RENAL score: $1 + 2 + 2 + p + 3 = 8p$, Fig. 1a) received RAPN by retroperitoneal approach. Da Vinci Xi® (Intuitive Surgical Inc, Sunnyvale, CA, USA) was used and the ports were located as shown in Figure 1b. AirSeal Intelligent Flow System® (CONMED, Largo, FL, USA) was used as

Fig. 1 (a) Contrast-enhanced CT scans of the patient. 2 cm tumor is located on the dorsal aspect of the left kidney (RENAL score: $1 + 2 + 2 + p + 3 = 8p$). (b) Five ports layout. Four robot arms are used including the extra arm. AirSeal Intelligent Flow System® (CONMED, Largo, FL, USA) was used as the pneumoperitoneum device.

pneumoperitoneum device. The surgery was started at a pneumoperitoneum pressure of 10 mmHg. PEEP was turned off, pneumoperitoneum pressure was increased to 15 mmHg, and tumor resection was started with renal artery clamping. Torn vessels were identified on the resection surface (Fig. 2). $EtCO_2$ suddenly declined to 25 mmHg and SpO_2 dropped to 92% (Fig. 3) 5 min after the beginning of tumor excision; $PaCO_2$ conversely increased to 74.9 mmHg on blood gas analysis. Pulmonary artery gas embolism may have occurred. Pneumoperitoneum pressure was immediately dropped to 8 mmHg and PEEP was restarted. Tumor resection was quickly completed, resected surface was compressed with gauze, and recovery of the patient's condition was waited on. $EtCO_2$ was recovered to 35 mmHg 20 min later. Torn vessels and urinary tract at the resection surface were closed with inner sutures. Oxygenation was stabilized and $PaCO_2$ decreased to 43.7 mmHg. After awakening, patient's condition was generally good, and no neurological symptoms were observed, so we did not perform image inspection in consultation with anesthesiologist. Total operative time was 176 min, with an ischemia time of 18 min. The pathological diagnosis of the tumor is clear cell carcinoma, and the diameter of the resected specimen was 48 mm, while the tumor diameter was 19 mm. Surgical margin was negative.

Discussion

CO2 embolism causes interruption of pulmonary artery, resulting in alveolar dead space, which inhibits ventilation, resulting in decrease in $EtCO_2$ and increase in PaCO2.[4] These parameters are important in diagnosing. CO_2 embolism presents with systemic hypotension, dyspnea, cyanosis, tachycardia or bradycardia, arrhythmia, or asystole.[5] It is necessary to monitor patient's progress after the surgery to see if there are any neurological symptoms caused by cerebral infarction. Li *et al.* reported cerebral infarction case due to CO_2 embolism after laparoscopic partial nephrectomy, which was associated with postoperative hemiparesis, vomiting, and deep sedation.[6]

Effective imaging examinations in gas embolism include TEE and CT, which can confirm gas in vessels.[4,7] It is difficult to obtain CT scan intraoperatively. Therefore, we think it is ideal to use TEE intraoperatively and CT as postoperative follow-up.

If gas embolism is diagnosed, immediately lower pneumoperitoneum pressure and resume PEEP. Ventilation with 100% oxygen is necessary to wash out CO_2 and improve hypoxemia. In order to prevent further gas from reaching pulmonary and cerebral bloodstreams, it is effective to place patient in the left-lateral or Trendelenburg position.[8] Inserting central venous or pulmonary artery catheter and directly aspirating gas in right atrium or ventricle is also effective.[9]

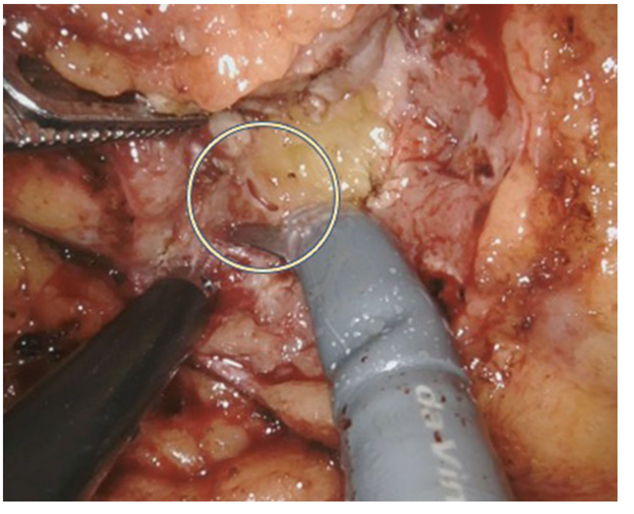

Fig. 2 Torn venous vessel during renal tumor resection.

Gas embolism occurs when pneumoperitoneum pressure exceeds venous pressure, causing CO_2 to flow into veins (Fig. 4a). At the time of partial nephrectomy in this case, there was minimal bleeding from the resection surface. Pneumoperitoneum pressure was routinely increased to control bleeding during partial nephrectomy in an attempt to reduce blood loss, which increases risk of CO_2 inflow because torn vessel is exposed to resection surface. It is important to establish clear resection surface with careful hemostasis, rather than relying solely on pneumoperitoneum pressure. Conversely, more bleeding makes it more difficult for surgeon to perform tumor resection if pneumoperitoneum pressure is lower than venous pressure (Fig. 4b). Bleeding cannot only be suppressed but gas embolism development can also be prevented if pneumoperitoneum pressure is equal to venous pressure (Fig. 4c). Venous pressure is usually 8–10 mmHg.[10] However, optimal pneumoperitoneum pressure varies in each case because venous pressure varies depending on various factors. Airway pressure is one of the factors that affect venous pressure. Intrathoracic pressure is also raised as ventilator-induced airway pressure is raised, increasing central venous pressure. Venous pressure is high in obese patients due to increased airway pressure caused by decreased chest compliance.[11] Several other factors that can affect venous

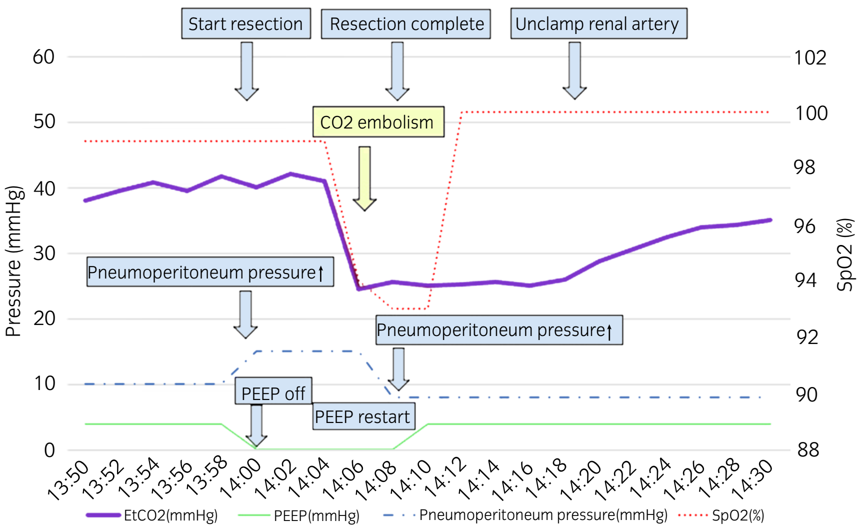

Fig. 3 Vital signs during partial nephrectomy. Since $EtCO_2$ and SpO_2 decreased rapidly, it was determined to be CO_2 embolism. Pneumoperitoneum pressure was immediately lowered, PEEP was restarted, and tumor resection was quickly completed. The $EtCO_2$ was recovered to 35 mmHg 20 min later.

pressure have been noted.[10] Further studies are needed to determine appropriate partial nephrectomy pressure.

In addition, tumor was located close to renal hilus in this case. The closer tumor is to renal hilus, the closer to major vessels, and thus more likely that larger teared vessel will be exposed on resection surface. This may result in a higher probability of CO_2 embolism. Also, as shown in Figure 1, tumor contained a cystic component. If tumor is adjacent to a cyst, it is important to note that attempting to resect the cyst without rupturing it inevitably forces wider margin, which may result in easier inflow of gas.

We suggest several preventive steps to reduce the risk of developing gas embolism during partial nephrectomy. First, arterial bleeding needs to be stopped by clamping. Second, setting a low pneumoperitoneum pressure at the beginning of partial nephrectomy and gradually increasing in case of massive bleeding may be useful. This procedure may provide optimal insufflation pressure for each patient. In addition, AirSeal was used during the surgery. While this device can maintain a more stable insufflation pressure than normal insufflation device, it also allows higher flow of CO_2 into the body.[7] Setting lower pneumoperitoneum pressure may be possible when using this type of insufflation device.

In conclusion, sufficient attention should be focused to gas embolism occurrence when performing RAPN, especially during tumor resection. Adjusting the optimal pneumoperitoneum pressure for each case is important to prevent both hemorrhage and gas embolism.

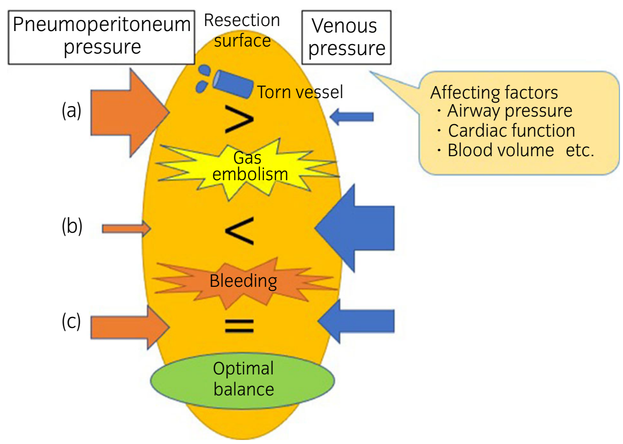

Fig. 4 The mechanism of gas embolism and bleeding during tumor resection. (a) Gas embolism occurs when the pneumoperitoneum pressure exceeds the venous pressure. (b) Bleeding occurs when the venous pressure exceeds the pneumoperitoneum pressure. (c) The ideal pneumoperitoneum pressure should be equal to the venous pressure, but the optimal pressure varies from case to case due to various factors that affect the venous pressure.

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Author contributions

Ryunosuke Nakagawa: Data curation; writing – original draft. Takahiro Nohara: Conceptualization; writing – review and editing. Suguru Kadomoto: Data curation; investigation. Hiroaki Iwamoto: Data curation; investigation. Hiroshi Yaegashi: Data curation; investigation. Masashi Iijima: Investigation. Shohei Kawaguchi: Investigation. Kazuyoshi Shigehara: Supervision. Kouji Izumi: Supervision; validation. Yoshifumi Kadono: Validation. Atsushi Mizokami: Supervision.

Conflict of interest

The authors declare no conflict of interest.

Approval of the research protocol by an Institutional Reviewer Board

Not applicable.

Informed consent

Informed consent was obtained from the patient.

Registry and the Registration No. of the study/trial

Not applicable.

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