Cardiac arrest associated with use of an argon beam coagulator during laparoscopic cholecystectomy

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We describe a cardiac arrest during use of an argon beam coagulation (ABC) system in an 82-yr-old woman having laparoscopic cholecystectomy under general and epidural anaesthesia. Intra-abdominal pressure (IAP) was controlled to less than 12 mm Hg during a carbon dioxide gas pneumoperitoneum and at first the operation was uneventful. When the ABC system (gas flow 6 litre min⁻¹) was used to control local bleeding in the liver bed abdominal pressure increased rapidly to over 20 mm Hg and, 1 min later, the end-tidal carbon dioxide decreased to zero, followed by bradycardia and cardiac arrest. At once, an emergency laparotomy was performed and resuscitation begun. A mill-wheel murmur was heard on auscultation, leading to suspicion of argon gas embolism. Fortunately, recovery was completed with no neurological deficit. Anaesthesiologists should consider showed that argon gas embolism can occur with the ABC system during laparoscopic surgery.

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Argon beam coagulation (ABC), in which electrosurgical coagulation is produced by a jet of inert argon gas encompassing an electrofulguration arc, is a useful technique during laparoscopic surgery. However, when ABC systems are used in closed cavities, such as in laparoscopic procedures, there is a risk of argon gas embolism caused by intra-abdominal over-pressurization.1–3 We report a cardiac arrest during laparoscopic surgery using an ABC system, when pulmonary argon gas embolism was strongly suspected.

Case report

An 82-yr-old, 160-cm, 48-kg woman with no history of cardiopulmonary disease or deep venous thrombosis was to undergo laparoscopic cholecystectomy. Her pre-operative chest radiograph showed nothing of note and her electrocardiogram revealed only asymptomatic IRBBB. She was not premedicated for the surgery. After insertion of a peripheral i.v. canula, an epidural catheter was placed at the Th10–11 interspace. The epidural catheter position was checked with a test dose of 60 mg mepivacaine with 15 μg epinephrine. Before induction of anaesthesia arterial pressure was 132/78 mm Hg, and heart rate was 68 beats min⁻¹. After pre-oxygenation, 1 mg vecuronium and 50 μg fentanyl were given intravenously followed by 70 mg propofol, and 5 mg vecuronium to facilitate tracheal intubation. A continuous electrocardiogram, pulse oximetry, end-tidal carbon dioxide and non-invasive blood pressure were monitored. Anaesthesia was maintained with sevoflurane and nitrous
oxide in oxygen, and 50 mg mepivacaine was administered intermittently via the epidural catheter. Additional vecuronium (1 mg) was given every 20 min. A pneumoperitoneum (surgical carbon dioxide insufflator, Type A5645, Olympus Optical Co. Ltd, Tokyo, Japan) was created by insufflation of carbon dioxide gas via a trocar 1 cm above the navel. Intra-abdominal pressure was regulated to less than 12 mm Hg. End-tidal carbon dioxide was kept within the range 30–35 mm Hg. Approximately 1 h after the beginning of the operation, the surgeon began to use an ABC (Conmed 6500; Conmed, NY, USA: gas flow 6 litre min⁻¹) while resecting between liver bed and gall bladder. This was done to control local bleeding because the monopolar electrocautery was ineffective. Soon after this application of ABC, intra-abdominal pressure increased rapidly to more than 20 mm Hg and, 1 min later, the waveform of the capnogram suddenly disappeared. This was followed by bradycardia (HR=20–30 beats min⁻¹) and a decrease in systolic arterial pressure from 120 to 72 mm Hg. At once, 8 mg ephedrine and atropine 0.5 mg were administered intravenously, and ventilation with 100% oxygen was started. At the same time, the pneumoperitoneum was discontinued and the surgeon started an emergency laparotomy to control bleeding. Active bleeding was not found. In spite of these efforts, progressive arterial desaturation developed and cardiac arrest occurred. A millwheel murmur was heard on auscultation of the chest. The patient was moved to the head-down position because desaturation developed and cardiac arrest occurred. A millwheel murmur was heard on auscultation. The most likely explanation for the cardiac arrest is that high-flow argon entered the opened hepatic vein when abdominal pressure was increased. Using an argon gas stream to form an ionized arc enhances electro surgical coagulation. The jet flow of argon gas clears the bleeding away from the surgical field and allows coagulation of the surface under direct vision. However, argon can enter open blood vessels, with possibly fatal gas embolism. Although argon is physiologically inert, it is 17 times less soluble than carbon dioxide (0.029 vs 0.495 ml gas ml⁻¹ blood). For this reason, argon-rich emboli are not as readily absorbed and may pass into the systemic circulation. In an animal study, the number of venous gas bubbles depended on the gas flow rate, and the incidence of gas embolism increased when argon gas flow exceeded 12–15 litre min⁻¹. Unfortunately, most laparoscopic insufflators do not regulate intra-abdominal pressure by actively venting excess gas from the peritoneal cavity, and they, therefore, cannot relieve increased pressure caused by the ABC system. Consequently, even if abdominal pressure increased above the insufflator’s alarm limit, the ABC system would continue to supply argon. Although flow rates of 2–4 litre min⁻¹ have been recommended for laparoscopic procedures, we increased the gas flow to 6 litre min⁻¹ because the surgeons could not control local bleeding at a gas flow of 4 ml min⁻¹. As a result, abdominal pressure exceeded 20 mmHg. In closed cavities, the ABC system acts as a secondary source of pressurized gas. We did not stop giving nitrous oxide when using the argon beam coagulator. Diffusion of nitrous oxide into the peritoneal cavity could increase the volume of gas and increase the intraperitoneal pressure even further. Manufacturers are already aware of the risk of gas embolism during laparoscopic use of ABC systems and provide specific instructions to minimize the associated risks. This is indicated by the following recommendations: (1) the initial setting should be manual mode and the argon flow should be kept at the lowest level consistent with efficient system performance (i.e. 4 litre min⁻¹ or less), (2) one instrument cannula vent should be left open to the atmosphere during the use of an ABC system and the electrode should be removed from the body cavity when ABC is not actually being performed, (3) only laparoscopic insufflators with non-defeatable audible and visual over-pressurization alarms should be used, and (4) the manufacturer’s specific

**Discussion**

Several causes for the cardiac arrest were possible, such as hypovolaemia, vagal reflex, or argon or carbon dioxide gas embolism. As the total infusion volume was 1750 ml of crystalloïd, blood loss was only 100 g up to the occurrence of the cardiac arrest, urine output was more than 200 ml, and active bleeding was not seen we can more or less exclude the possibility of hypovolaemia. The abrupt increase in IAP to over 20 mm Hg induced by the ABC system could have reduced cardiac output secondary to an acute decrease in venous return. During light anaesthesia with the combination of general and epidural, a vagal reflex could occur. Sympathetic block by epidural anaesthesia could worsen cardiovascular decompensation during the head-up position. We cannot entirely exclude this possibility. A definitive diagnosis of an argon gas embolism requires the aspiration of gas bubbles and detection by transoesophageal Doppler. Argon could also accumulate in the peritoneal cavity, and the embolism could have been with a mixture of argon and carbon dioxide. However, the cardiac event occurred immediately after the use of the ABC system and a millwheel murmur was heard on auscultation. The most likely explanation for the cardiac arrest is that high-flow argon entered the opened hepatic vein when abdominal pressure was increased. Using an argon gas stream to form an ionized arc enhances electrosurgical coagulation. The jet flow of argon gas clears the bleeding away from the surgical field and allows coagulation of the surface under direct vision. However, argon can enter open blood vessels, with possibly fatal gas embolism. Although argon is physiologically inert, it is 17 times less soluble than carbon dioxide (0.029 vs 0.495 ml gas ml⁻¹ blood). For this reason, argon-rich emboli are not as readily absorbed and may pass into the systemic circulation. In an animal study, the number of venous gas bubbles depended on the gas flow rate, and the incidence of gas embolism increased when argon gas flow exceeded 12–15 litre min⁻¹. Unfortunately, most laparoscopic insufflators do not regulate intra-abdominal pressure by actively venting excess gas from the peritoneal cavity, and they, therefore, cannot relieve increased pressure caused by the ABC system. Consequently, even if abdominal pressure increased above the insufflator’s alarm limit, the ABC system would continue to supply argon. Although flow rates of 2–4 litre min⁻¹ have been recommended for laparoscopic procedures, we increased the gas flow to 6 litre min⁻¹ because the surgeons could not control local bleeding at a gas flow of 4 ml min⁻¹. As a result, abdominal pressure exceeded 20 mmHg. In closed cavities, the ABC system acts as a secondary source of pressurized gas. We did not stop giving nitrous oxide when using the argon beam coagulator. Diffusion of nitrous oxide into the peritoneal cavity could increase the volume of gas and increase the intraperitoneal pressure even further. Manufacturers are already aware of the risk of gas embolism during laparoscopic use of ABC systems and provide specific instructions to minimize the associated risks. This is indicated by the following recommendations: (1) the initial setting should be manual mode and the argon flow should be kept at the lowest level consistent with efficient system performance (i.e. 4 litre min⁻¹ or less), (2) one instrument cannula vent should be left open to the atmosphere during the use of an ABC system and the electrode should be removed from the body cavity when ABC is not actually being performed, (3) only laparoscopic insufflators with non-defeatable audible and visual over-pressurization alarms should be used, and (4) the manufacturer’s specific
recommendations should be followed and staff should be trained to detect and manage gas embolization during laparoscopic procedures.

In summary, venous gas embolism can occur when an ABC system is used during laparoscopic procedures. Strict adherence to the manufacturer’s instructions, and careful monitoring to allow early detection of gas embolism, such as use of transoesophageal Doppler, are important when an ABC system is used.

References
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