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Fatal Carbon Dioxide Embolism Complicating Attempted Laparoscopic Cholecystectomy— Case Report and Literature Review

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ABSTRACT: Laparoscopic cholecystectomy has become the surgical procedure of choice for individuals with symptomatic gallbladder disease. The procedure has gained popularity among surgeons and patients because of inconspicuous abdominal incisions/scars, less postoperative pain, shorter hospitalization, and reduced medical costs. Bile duct, vascular, and gastrointestinal iatrogenic injuries are major complications.

We describe the case of a 50-year-old woman who died of CO_2 embolism during elective laparoscopic cholecystectomy for symptomatic cholelithiasis. With the patient under general anesthesia, a 1.5 cm incision was made just below the umbilicus, and a pneumoperitoneum was created by CO_2 insufflation with a pneumoperitoneum (modified Veress) needle. Immediately, she experienced a cardiopulmonary arrest and could not be resuscitated. At autopsy, air bubbles were admixed with blood in the epicardial veins and leptomeningeal blood vessels. A triangular 0.1 cm perforation in the left common iliac vein had been created by the pneumoperitoneum needle.

A pneumoperitoneum is required for laparoscopy and CO_2 is the most commonly used gas. Carbon dioxide is highly soluble in blood and fairly innocuous to the peritoneum. Small amounts absorbed into the circulation cause slight increases in arterial and alveolar CO_2 and in central venous pressure. When CO_2 enters the venous circulation through iatrogenically opened vascular channels, catastrophic and potentially fatal hemodynamic and respiratory compromise may result.

KEYWORDS: pathology and biology, carbon dioxide embolism, laparoscopic cholecystectomy, surgical complication

Laparoscopic cholecystectomy (LC) has become the preferred treatment of symptomatic cholelithiasis. The advantages of LC over open cholecystectomy include inconspicuous scars, less postoperative pain, decreased hospitalization, and earlier return to normal activities. The number of gallbladders removed by LC in the United States has gone from zero in 1987 to more than three-fourths of the cholecystectomies currently being performed [*1*]. The rapid establishment of LC has occurred without controlled clinical trials. This has generated concern about procedural complications that include injuries to bile ducts, the

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gastrointestinal tract, and blood vessels. We report the first fatal carbon dioxide embolism complicating laparoscopic cholecystectomy. The iatrogenic perforation of left common iliac vein by the pneumoperitoneum needle allowed the insufflating CO_2 to enter the venous system.

Case Report

A 50-year-old woman had complained of daily right upper quadrant pain for a month and intermittent abdominal pain for an unspecified number of years. She had experienced occasional nausea and vomiting after eating fatty foods. An abdominal ultrasound disclosed cholelithiasis but no ductal dilatation. An upper gastrointestinal barium meal showed a small sliding hiatal hernia with gastroesophageal reflux. Her past medical history was significant for mild systemic hypertension controlled with hydrochlorothiazide. A hysterectomy with bilateral salpingo-oophorectomy had been performed for leiomyomata and endometriosis. Besides her antihypertensive medication, she was taking ranitidine and conjugated estrogen tablets. The clinical impression was cholelithiasis with biliary colic and she was scheduled for laparoscopic cholecystectomy.

In the operating room she was placed supine and general anesthesia induced. After sterilely prepping the abdomen, a 1.5 cm transverse subumbilical incision was carried down through the skin and subcutaneous tissue. Towel clips were applied to the adjacent skin to pull the abdomen upward. The Veress or pneumoperitoneum needle was inserted into the abdomen without difficulty and cleared with saline. The Veress needle was connected to the carbon dioxide source and the CO_2 was started at a low flow rate. The abdomen was insufflated with about two liters of CO_2 to a pressure of 12 mm Hg. Immediately, her heart rate dropped to 30 beats per minute and her systolic blood pressure plummeted to 60 mm Hg. Advanced cardiac life support measures were instituted. A temporary cardiac pacemaker was inserted but no femoral or carotid pulses could be detected. After 2 hours and 45 minutes of resuscitative efforts, she was pronounced dead.

At autopsy the body weighed 88.2 kg and measured 162.6 cm. Indications of previous surgeries included a 17 cm well-healed transverse scar on the lower abdomen and a well-healed, vertical 6 cm subumbilical scar.

The coronary veins and coronary sinus contained multiple minute air bubbles (Fig. 1). Similar air bubbles were within leptomeningeal vessels. Below the aortic bifurcation, the retroperitoneal soft tissue contained a 5 × 3 × 2 cm area of extravasated blood (Fig. 2). The left common iliac vein exhibited a 0.1 cm perforation that extended through the anterior and posterior walls (Fig. 3). The perforation corresponded to the size and shape of the Veress or pneumoperitoneum needle's tip (Fig. 4).

The gallbladder wall was slightly thickened and measured to 0.4 cm. The gallbladder contained 30 mL of dark green-brown mucoid bile and 20 to 30 multifaceted mixed concretions ranging in size from 0.2 to 0.9 cm. The remaining internal organs exhibited no significant abnormalities.

The cause of death was carbon dioxide embolism occurring as a complication of laparoscopic cholecystectomy.

Discussion

Cholelithiasis has a prevalence of 5 to 22% in the Western World. Until recently open cholecystectomy had been the most commonly performed general surgical procedure and the accepted treatment for symptomatic gallstones with a mortality rate of 0.05% [2–4]. Alternative treatment modalities for cholelithiasis leaving the gallbladder intact such as oral dissolution therapy, extracorporeal shock wave lithotripsy, contact dissolution therapy, and percutaneous stone removal allow gallstone recurrence. Estimates indicate that as many

FIG. 1—*Air and blood* (arrows) *admixed within epicardial veins (in situ).*

as 20 million Americans have gallstones and 500,000 cholecystectomies are performed annually in this country [*5*]. The total annual medical costs are about $1 billion, which does not include loss of wages, productivity, and postoperative morbidity [*6*].

Gynecologists have used diagnostic laparoscopy extensively for the last two decades. Laparoscopic cholecystectomies were first performed in the United States in 1988 following French reports of the procedure [*7*]. The first LC took place in Lyon, France in March of 1987 when Philipe Mouret removed the diseased gallbladder of a woman following laparoscopic gynecologic surgery [*8*]. Reddick and Olsen reported the technique in the United States and compared their experience with open and laparoscopic cholecystectomies [*9*]. Since then, the endoscopic procedure has traversed the United States and by late 1992 about 15,000 surgeons in the United States had received some training in the procedure and 80 to 90% of cholecystectomies employ this technique [*3,10*]. Since the introduction of LC for symptomatic cholelithiasis, the rate of cholecystectomy has almost doubled in some health care settings without any change in the risk pool or population served [*11*].

FIG. 2—*Retroperitoneal extravasated blood and soft tissue have been dissected away exposing the perforated left common iliac vein* (arrow).

Laparoscopic cholecystectomy creates inconspicuous abdominal incisions and puncture wounds and reportedly causes less postoperative pain, reduces length of hospitalization, permits earlier return to work, diminishes operative trauma without compromising visualization, and lessens wound complications [*12–22*]. With its promise of less postoperative pain and shorter recovery time, patient demand has propelled the implementation of this new technique before prospective research could be implemented. No large randomized trials comparing laparoscopic and open cholecystectomy have been undertaken [*23*]. Relative and absolute contraindications for LC have been published but these are constantly being revised as laparoscopically trained surgeons gain more experience [*24–28*].

Laparoscopic cholecystectomy requires that the surgeon attain new skills in manipulating instruments while viewing the procedure through a video monitor [*29,30*]. Patients undergoing laparoscopic cholecystectomy are given general anesthesia using endotracheal intubation. A catheter is removed preoperatively after the urinary bladder is drained. The patient must be monitored for dysrhythmias, change in blood pressure, and alteration in heart rate [*29*].

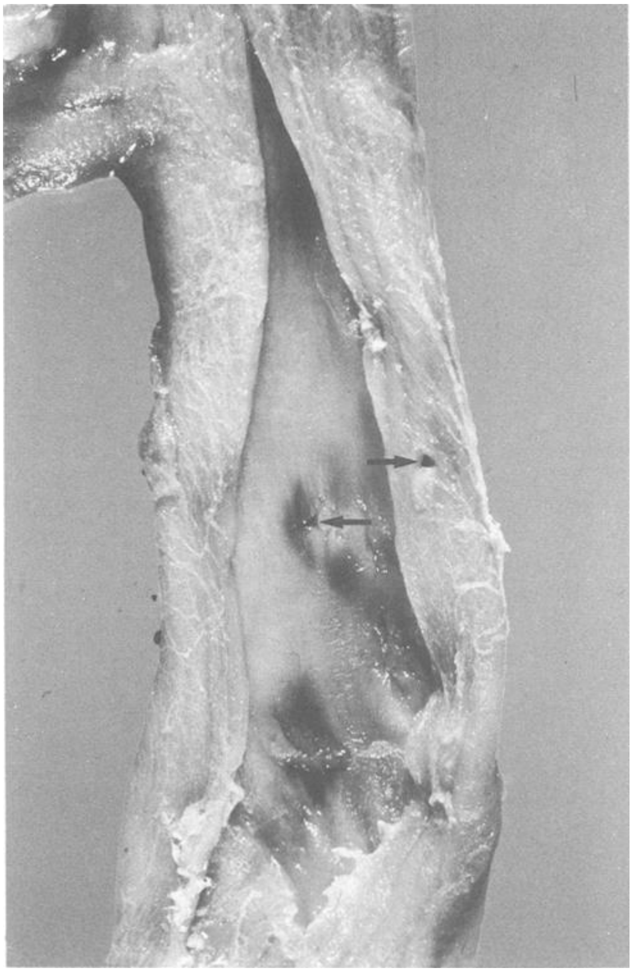

FIG. 3—*Left common iliac vein with perforations* (arrows).

A nasogastric tube keeps the stomach and duodenum empty. The patient is placed supine with the surgeon and camera operator on the patient's left side and the assistant at the patient's right side. A pneumoperitoneum is established utilizing carbon dioxide with a modified Veress needle introduced subumbilically while the patient is in the Trendelenburg position [*31,32*]. Nitrous oxide, oxygen, and air have been used; however, carbon dioxide is more readily absorbed by tissues [*33–35*]. Initial insufflation pressure is 15 mm Hg or less [*29*]. During laparoscopy intra-abdominal pressure (IAP) rises above inferior vena caval (IVC) pressure; however, femoral vein pressure increases proportionally with the IAP thus maintaining blood flow through the IVC [*36–38*].

A periumbilical incision allows insertion of a 10 mm laparoscope attached to a videocamera. Secondary cannulas are placed in the right anterior axillary line, right midclavicular line, and subxiphoid area. Adhesions are divided by blunt and sharp dissection. The gallbladder is grasped by forceps inserted through a 5 mm lateral port and retracted cephalad [*2*]. Dissection of the gallbladder is performed using instruments inserted through the midline and midclavicular ports. The cystic artery and duct are ligated with clips. The gallbladder is removed

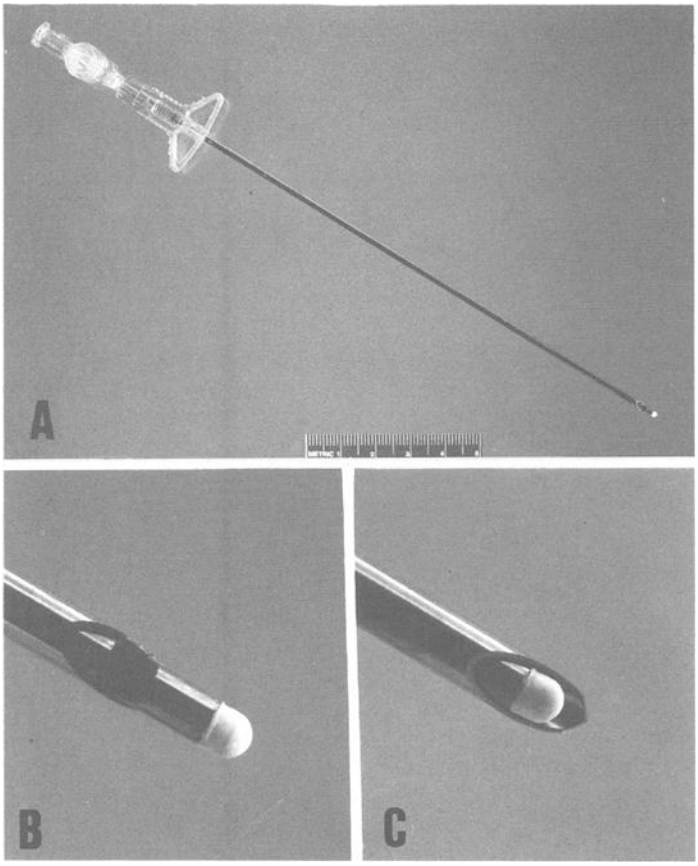

FIG. 4—*Pneumoperitoneum needle* (A), *inner obturator with lateral port* (B), *and trocar's tip with obturator retracted* (C).

from its bed by blunt dissection and the hepatic bed is inspected for hemostasis before final extraction. The excised gallbladder is removed through the umbilical port. The fascia and skin at the portal sites are closed with sutures. Variations in technique and instrumentation have been described [*24,39–50*].

Infrequent reports of complications persuaded a National Institutes of Health consensus conference and the majority of an American Medical Association Diagnostic and Therapeutic Technology Assessment panel to interpret the procedure as safe and effective [*3,23,29*]. The incidence of bile duct injuries during laparoscopic cholecystectomies is increased when compared to open cholecystectomies [*51–55*]. Major complications of laparoscopic cholecystectomy include injury to bile ducts (excluding cystic duct), perforation of retroperitoneal or portal blood vessels, and injuries involving the gastrointestinal tract [*56–58*]. Vascular and bowel injuries are the leading fatal complications. Major bile duct injury accounts for less than 2% of fatal complications [*1*].

Reported case-mortality rates vary from 0 to 0.5%; however, the cause of death is not always apparent from LC articles and it is unclear what percentage of deaths associated with LC were autopsied [*4–6,12,42,59–64*]. Consequently, the reported operative mortality rates may underestimate the true mortality rate of the procedure. More than half of the reported deaths following LC are attributable to a technical complication [*1*]. A comparable frequency of technical complications occurring during open cholecystectomy would be considered excessive [4]. In earlier studies surgeons excluded high risk individuals from LC but as surgeons gain more experience with the technique, some predict more high risk individuals will undergo the procedure leading to higher conversion and complication rates [59]. Postoperative deaths following open cholecystectomy usually result from cardiovascular disease, and deaths related to a technical complication are exceedingly rare [65,66].

Establishment of the initial pneumoperitoneum can be associated with malposition of the Veress cannula with injury to solid or hollow viscera causing gas embolism [67–74]. The Veress or pneumoperitoneum needle is a double-barrelled cannula with a sharp tipped outer sheath (trocar) covering a hollow, blunt tipped inner spring loaded obturator equipped with lateral ports for gas insufflation [31]. Embolization of the insufflating gas during induction of pneumoperitoneum for laparoscopy is a sudden, dramatic event caused by accidental perforation of intra-abdominal veins with subsequent intravascular gaseous embolization [75].

Gas embolism is always a possibility when gas in insufflated under positive pressure into a body cavity [69]. The first reported fatal gas embolism during peritoneoscopy verified by autopsy is credited to Jernstrom [76]. Unfortunately, diagnostic clinical criteria for gas embolism varies considerably in the literature and the true incidence is difficult to obtain. The only absolute criteria for the diagnosis of gas embolism are verification of gas bubbles in the inferior vena cava, right atrium, or epicardial veins radiographically or by direct visualization at surgery or autopsy [61,77–79]. When hypotension or acute pulmonary edema develops during insufflation of gas, gas embolism must be suspected and the insufflation terminated immediately, releasing any gas already introduced [67,80–84]. Signs of gas embolism include a splashing hydroaeric "millwheel" murmur, tachydysrhythmias, sudden increase followed by an abrupt drop in end-tidal CO_2 (ET_{CO_2}), tachypnea, diffuse pulmonary wheezing or gasping, apnea, change in central venous or pulmonary arterial pressures, and deep cyanosis of the head and neck indicative of superior vena caval, tricuspid valvular, or pulmonary outflow obstruction by a gas lock phenomenon [85–89]. The obstruction in venous return causes a precipitous fall in cardiac output. Cardiac contractions break the gas up into small bubbles producing a foam, which on reaching the pulmonary circulation, creates pulmonary hypertension and right heart strain [75,77]. Following CO_2 embolization an initial increase in ET_{CO_2} occurs reflecting CO_2 excretion by the lungs from carbon dioxide absorbed into the blood [87]. The abrupt drop in ET_{CO_2} occurs as the pulmonary arterioles are blocked by the CO_2 embolus increasing alveolar dead space. A small, incomplete CO_2 embolus may show only an increase in ET_{CO_2} without a subsequent decrease [87]. The situation is similar to air embolism but not as devastating since CO_2 does not cause bronchospasm or pulmonary compliance changes as does air [87,90]. If carbon dioxide embolization is not recognized and gas insufflation continues, other gases, mainly O_2, will diffuse into and enlarge the bubbles creating gaseous emboli that will require even more time to be absorbed [87,90,91]. Acute right ventricular hypertension may open a patent foramen ovale permitting coronary artery embolism [74,92]. Systemic hypotension may be exacerbated because a sudden increase in arterial CO_2 can cause a marked reduction in peripheral vascular resistance [92].

If gas embolism develops, the patient is turned to the left lateral decubitus (Durant) position and a central line is inserted to aspirate gas from the venous system [67,93]. Gas embolism during diagnostic laparoscopy is rare but can cause ventricular fibrillation, cerebral dysfunction, and sometimes death [33,36,37]. The amount and flow rate of intravascular CO_2 necessary to produce death is variable. Up to 200 mL of CO_2 have been used intravenously in humans as a diagnostic tool without complications [34,69,92]. Large volumes of gas (3 to 8 mL/kg) injected rapidly can be immediately fatal [94,95]. Procedures to avoid this catastrophic complication include aspirating the Veress needle before insufflating with gas to prevent direct introduction of CO_2 into a blood vessel, placement of an intraesophageal or precordial stethoscope or Doppler monitor to detect cardiac murmurs, capnography to monitor ET_{CO_2}, and direct visualization when inserting the pneumoperitoneum cannula [*36,56,64,75,85,96–110*].

Puncture of viscera cannot always be detected by negative aspiration of the pneumoperitoneum needle [*111,112*]. Fatal gas embolism complicating gynecologic laparoscopy has been reported, and two of these fatalities occurred when the left common iliac vein was perforated by the pneumoperitoneum needle [*68,71*]. Gas embolism during laparoscopy has been reported with no obvious entry of the Veress needle into a blood vessel [*85*]. Near fatal CO_2 embolism during laparoscopy and hysteroscopy has been successfully treated with cardiopulmonary bypass [*85*]. Neurologic impairment following cardiovascular collapse from CO_2 embolism can be due to cerebral gas embolism and has been successfully treated with hyperbaric oxygen therapy [*113*]. The manifestations of cerebral gas embolism are variable and include sudden death, coma, seizure, visual disturbance, confusion, personality change, aphasia, vertigo, headache, and focal sensory or motor deficits [*113*].

The differential diagnosis of sudden death occurring during laparoscopy must include aspiration, dysrhythmias from atherosclerotic coronary artery disease, myocardial infarction, hypercarbia or halothane anesthesia, vasovagal reflex, intra-abdominal hemorrhage, pneumothorax, pneumomediastinum, pulmonary thromboembolism, diaphragmatic rupture, and excessive intra-abdominal pressure [*32,67,75,77,114–116*].

Formal postresidency training of surgeons in laparoscopic cholecystectomy has been mainly fulfilled by 1 or 2 day courses coupled with an *in vivo* animal LC; however, the ability of these courses to suffice as the only instructional foundation for LC has been challenged [*8,117–126*]. The rapid dissemination of this minimally invasive technology to the surgical community has bypassed the traditional methods of scientific assessment and development of laparoscopic privileging criteria [*127,128*]. Articles on laparoscopic cholecystectomy denote variable consensus among surgeons, medical staffs, and hospital governing committees regarding the appropriate supervision of nascent laparoscopic surgeons [*23*]. Allegations have been made of increased complication rates among surgeons during the early period following the completion of laparoscopic training [*119,120*].

Complications appear to be inversely proportional to the number of laparoscopic cholecystectomies performed by the surgeon [*3,29,129*]. Lack of additional training has been the only surgeon-dependent variable that is predictive of increased laparoscopic complication rates [*130*]. The Society of Gastrointestinal Endoscopic Surgeons has published credentialing standards, but it is unknown if these have been adopted by hospitals or surgeons in other professional groups [*23,131,132*]. Many institutions have succumbed to marketplace pressures and have adopted less rigorous criteria [*133,134*]. Complication rates decrease as more procedures are performed, and additional training may shift the individual surgeon's position on the learning curve to the right [*130*].

The introduction of LC probably represents one of the greatest changes in general surgical technique of the last 50 years; however, it has not so much revolutionized general surgery as it is an optional technique in removing a diseased gallbladder [*53*]. The procedure causes less tissue damage, less blood loss, shorter hospitalization, and quicker return to work. Endoscopic removal of diseased gallbladders has been made possible by new imaging modalities, improved optical systems, and specialized surgical instruments [*98*]. Major complications include injury to the bile ducts, intestines, and perforation of blood vessels. The case-fatality rate for LC is comparable to open cholecystectomy; however, more than 50% of the major complications following LC are related to surgical technique. Access to the abdomen for LC is usually by blind insertion of the pneumoperitoneum needle at the umbilicus, inflating the abdomen with several liters of CO_2 and inserting a trocar through the same site. Procedures to reduce the risk of vascular and intestinal injuries during establishment of the pneumoperitoneum include direct visualization, thus mitigating potential injuries caused by the Veress needle or trocar [*98*]. Forensic pathologists must be aware that gas embolism is a rare but potentially fatal complication of establishing a pneumoperitoneum for laparoscopic guided procedures.

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