

following safeguards be routinely used during invasive pressure monitoring. First, the connecting cable should be visually inspected prior to connection to the transducer. Second, after zeroing the transducer to atmospheric pressure, the pressure-monitoring system should be checked against a mercury manometer. Care should be taken to perform the calibration check while the system is not connected to the patient, to avoid air embolus. Finally, the possibility of malfunction of the pressure-monitoring system should always be considered following sudden changes in invasive pressure readings.

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## Carbon Dioxide Embolism: Successful Resuscitation with Cardiopulmonary Bypass

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Carbon dioxide embolism is a well-known complication of laparoscopy. We present here a patient who experienced sudden, complete cardiovascular collapse during laparoscopy and hysteroscopy and who was resuscitated with cardiopulmonary bypass. This is the first report in the literature in which an almost certainly fatal CO<sub>2</sub> embolism was treated successfully with cardiopulmonary bypass.

#### CASE REPORT

The patient was a 28-yr-old woman who presented with a complaint of infertility and who was scheduled for laparoscopy, hysteroscopy, and resection of the uterine septum in our in hospital ambulatory surgery center.

Her past history was negative for any significant medical problems. She had undergone three dilation-and-curettage procedures in the past without any problems. Her only medication was danazol 200 mg three times per day. She had no known drug allergies.

On physical examination, she weighed 78 kg and was 163 cm tall. She had a blood pressure of 120/60 mmHg and a pulse of 85 beats

per min. There were no physical or laboratory abnormalities noted. Preoperative electrocardiogram and chest x-ray were not obtained.

In the operating room electrocardiogram, noninvasive blood pressure (Dinamap<sup>®</sup>) and hemoglobin O<sub>2</sub> saturation (SpO<sub>2</sub>) (pulse oximeter) monitoring was established. The patient was preoxygenated with 100% O<sub>2</sub>. Following administration of 3 mg *d*-tubocurarine and 100 µg fentanyl, anesthesia was induced with 375 mg thiopental and 150 µg fentanyl. One hundred milligrams succinylcholine was given to facilitate intubation of the trachea, after which an additional 125 mg thiopental was given to blunt the patient's hypertensive response to intubation. End-tidal CO<sub>2</sub> (PETCO<sub>2</sub>) monitoring was established, and an esophageal stethoscope and temperature probe were inserted.

Anesthesia was maintained with O<sub>2</sub>, N<sub>2</sub>O, and isoflurane. Thirty-five milligrams atracurium was given for surgical muscle relaxation. The patient's lungs were mechanically ventilated at a rate of 8 breaths per min and with a tidal volume of 650 ml. Laparoscopy and hysteroscopy were performed simultaneously. The abdomen was insufflated with CO<sub>2</sub> through a Verres needle inserted into the peritoneal cavity. (A Verres needle is a device with a sharp outer needle surrounding an inner blunt tipped cannula with a lateral hole through which gas may be administered.) A 32% solution of dextran 70 in 10% dextrose (Hyskon<sup>®</sup>) via an infusion set (catalog number 003712-901, Cabot Medical Corporation) was used to distend the uterus for the hysteroscopy and resection of the uterine septum.

Approximately 35 min after beginning the procedure and while performing the hysteroscopy, a few minutes after the uterine septum had been divided, the surgeons remarked that the distending pressure of the uterus had decreased and that perhaps the uterus had been perforated. Moments after that, there was a sudden bradycardia, followed by tachycardia of 160 beats per min, followed rapidly in turn by ventricular fibrillation and then asystole. The blood pressure was unmeasurable at that point. At the same time it was noted that there was an abrupt increase in the PETCO<sub>2</sub> (from 31 to 38 mmHg) and a decrease in the SpO<sub>2</sub> to 81%. The peak inspiratory pressure increased

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from 14 to 25 cmH<sub>2</sub>O. At that point the patient's face became deeply cyanotic.

Anesthesia was immediately discontinued and the lungs manually ventilated with 100% O<sub>2</sub>. Cardiopulmonary resuscitation was begun. The position of the endotracheal tube was verified by laryngoscopy and auscultation of breath sounds by three different attending anesthesiologists. During the resuscitation, the patient received atropine, epinephrine, bicarbonate, and calcium, and her heart was electrically defibrillated four times. The cardiac rhythm did not respond to these measures, and a cardiac surgical team was called in to open the chest for internal cardiac massage.

The chest was opened through a median sternotomy, and within 5 min the aorta and right atrium were cannulated and cardiopulmonary bypass initiated. Core temperature was immediately decreased to 28° C. A "gas-lock" was noted in the right atrium, causing an obstruction of the superior vena cava. The heart was distended and without any electrical activity. All four chambers were vented, and gas escaped from each chamber. Bubbles also were noted in the coronary arteries and veins. Gas venting continued throughout the entire procedure. Upon opening the chest, a small right tension pneumothorax was decompressed.

The patient was given antibiotics, steroids, and infusions of nitroglycerin, dopamine, and dobutamine. An ophthalmologist was called in to evaluate the patient's retinae for the presence of arterial bubbles. None was seen. Initially, the heart showed no activity whatsoever. After 45 min on bypass, the heart began to respond to electrical pacing, and eventually atrial fibrillation occurred. The patient was gradually warmed, and cardioversion restored the heart to normal sinus rhythm. Separation from cardiopulmonary bypass occurred after 1 h and 37 min, with the assistance of inotropic support (dobutamine infusion at a rate of 10 µg · kg<sup>-1</sup> · min<sup>-1</sup>). After the chest was closed, a pulmonary artery catheter was inserted percutaneously through the right internal jugular vein.

On the second postoperative day the patient awakened. Following discontinuation of mechanical ventilation, her trachea was extubated. On examination she exhibited mild right-sided hemiparesis and was mildly confused, but she was able to carry on a normal conversation. Petechiae were visible over her entire face and shoulders.

Electroencephalography and computed tomography scanning of the brain showed no abnormality. At the time of discharge 12 days later, the patient had recovered almost completely, with only mild short-term memory loss. Six months later she was able to return to work. A year and a half later, she was pregnant.

## DISCUSSION

Laparoscopy for both diagnostic and therapeutic purposes is a very common procedure. Widely held to be a safe procedure, it has mortality of 2.5 per 100,000 laparoscopic sterilizations and 5.2 per 100,000 diagnostic laparoscopies.<sup>1</sup> Gas embolism, a rare but potentially lethal complication of laparoscopy, has an incidence of 15 per 113,253.<sup>2-5</sup> The incidence may be higher when laparoscopy is associated with hysteroscopy.<sup>6</sup> Two cases of air embolism associated with hysteroscopy and the use of the neodymium:yttrium-aluminum-garnet laser have been reported recently.<sup>7</sup>

The events of the current case indicate CO<sub>2</sub> embolism as the cause of the cardiovascular collapse. The surgical findings of bubbles in the central venous circulation are

unequivocal. The deep cyanosis of the head and neck is consistent with superior vena caval obstruction by a gas-lock phenomenon. The capnography data support the contention that CO<sub>2</sub> was the gas involved.<sup>8</sup> With an embolism of any other kind, air or thrombus, one would expect a sudden decrease in PETCO<sub>2</sub> due to occlusion of a portion of the pulmonary vasculature, effectively increasing the pulmonary dead space. Cardiac arrest or severe circulatory compromise may also tend to increase pulmonary dead space and decrease the PETCO<sub>2</sub>. Although a classic "mill wheel" murmur was not noted, events progressed so rapidly that ventricular fibrillation occurred before any member of the operating room team listened specifically for that murmur.

The source of the CO<sub>2</sub> embolism is not clearly defined. There was no obvious entry of the Verres needle into a blood vessel. We have entertained two theories of CO<sub>2</sub> entry into the circulation. The first presupposes a continuous entrainment of small bubbles that were temporarily trapped in a larger vessel, where they coalesced into a large bubble of gas. The uterine septum had already been divided, providing such a portal of entry. A change of the patient's position suddenly released this large bubble into the central circulation, yielding a catastrophic embolic event.

The second theory involves the temporal association of the cardiovascular collapse with the loss of distending pressure in the uterus. The hysteroscope device distends the uterus by filling it with a 32% solution of dextran 70 in 10% dextrose (Hyskon®). Distending pressure is maintained with CO<sub>2</sub>. In the event that the dextran solution is exhausted, a cutoff valve is supposed to stop the free flow of CO<sub>2</sub>. If the cutoff valve failed for even a few seconds, a pressurized blast of CO<sub>2</sub> might have entered through an open vein, resulting in a gas embolism. The device used in the current case was subsequently tested, and no malfunctions were found. However, the valve apparatus was in the disposable part and had been discarded before testing. The Hyskon® infusion set has since been withdrawn from the market by the manufacturer because of the potential that the safety-check ball may not seal completely following depletion of Hyskon® from the set, thereby allowing CO<sub>2</sub> to leak into the patient.

This episode illustrates an important point in the debate between *in-hospital* and free-standing ambulatory surgery units. While "minor" surgery performed on healthy patients generally is a safe proposition, there is a small but finite risk of disaster. When the ambulatory surgery center is located within the context of a large hospital, the full resources of the hospital can be used in the event of disaster. Although we do not advocate that a cardiopulmonary bypass team be available for every laparoscopy, we believe that an in-hospital setting can contribute to the safety of outpatient surgery.

The author and operating staff of this case thank Thomas Lajos, M.D. and his cardiac surgical team. Without their efficient response to our call for help, the outcome would have been much different.

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## Early Respiratory Depression Following Intrathecal Fentanyl-Morphine Combination

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The use of spinal opioids is becoming increasingly popular in anesthesiology for the control of postoperative and obstetric pain. Morphine has enjoyed widespread acceptance when used epidurally, and the use of intrathecal morphine, particularly in obstetrics, is also increasing. Recent reports regarding the use of intrathecal fentanyl and of opioid combinations including fentanyl in obstetric patients have indicated they may have advantages over morphine while having a lower risk of respiratory depression.<sup>1-3,†</sup> The following case report illustrates that this perceived safety may be unwarranted.

### CASE REPORT

A 23-yr-old gravida II, para 0 woman at 39 weeks gestation presented late in the evening complaining of labor pains. A diagnosis of breech presentation had been made by her obstetrician 2 weeks earlier, and after extended discussion, the patient and her obstetrician opted for an elective cesarean delivery. Examination at the time of presentation to the labor suite confirmed the breech presentation, cervical dilation to 2 cm, and an active labor pattern. In preparation for an urgent cesarean delivery, preoperative anesthetic evaluation revealed an un-

remarkable medical history. Physical examination revealed a 67.5-kg, 160-cm woman in mild distress due to labor pain and was otherwise unremarkable. A subarachnoid blockade was planned to facilitate delivery.

Following hydration with 2 l lactated Ringer's solution, the patient was positioned sitting on the operating room table. Preservative-free morphine 0.2 mg and fentanyl 15 µg (total volume 0.7 ml) was drawn into a 1-ml tuberculin syringe; this was added to 100 mg hyperbaric lidocaine in 5% dextrose. Dural puncture was performed with a 26-G spinal needle at the L3-L4 interspace with return of clear cerebrospinal fluid (CSF). The anesthetic-opioid combination was injected, and the patient was placed in the supine position with left uterine displacement. A sensory level of T3 bilaterally was confirmed using the response to fluoromethane spray. Surgery proceeded uneventfully with delivery of a healthy girl, with Apgar scores of 8 (1 min) and 9 (5 min).

Approximately 25 min after initiation of the subarachnoid blockade, following delivery of the infant, the patient became rather abruptly somnolent. The only further medications that had been administered were oxytocin 20 µl added to the intravenous infusion and cefoxitin 2 g intravenously. Blood pressure and heart rate were stable at 110/55 mmHg and 88 beats per min, respectively. The patient was arousable verbally with moderate tactile stimulation and was otherwise appropriate, saying she felt very sleepy. Initially it was believed that the relief she felt after a stressful evening may have been the cause of her fatigue until the patient's hemoglobin oxygen saturation (SpO<sub>2</sub>) began to decrease and her observed respiratory rate became 2-4 breaths per min. Oxygen 10 l/min *via* face mask, which had been removed after delivery, was reapplied, and with occasional prompting to take a deep breath, SpO<sub>2</sub> > 90% was maintained through the remainder of the case.

On admission to the postanesthesia care unit (PACU), 45 min after initiation of the block, the patient was arousable to vigorous verbal stimulation; her blood pressure was 95/48 mmHg, her pulse 70 beats per min, and her respirations irregular with apneic periods of greater than 30 s. Level of sensory anesthesia to fluoromethane spray was again noted to be T3 and her grip strength good, with no apparent weakness of the upper extremities. When the patient did not arouse spontaneously after several minutes of observation, naloxone 0.08 mg was administered intravenously, with little apparent effect. This dose was repeated twice more. After the last dose (total naloxone administered, 0.24 mg) the patient became more alert and talkative, and

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