

Unfortunately, an even more disastrous error can be made with some machines still in use today, as evidenced by our current case report. If isoflurane (vapor pressure 238 mmHg at 20° C) accidentally is placed in a methoxyflurane (vapor pressure 22.5 mmHg at 20° C) vaporizer, the anesthetist, thinking he was giving isoflurane 1% (with the DM5000® at 24° C), actually would be administering isoflurane 10.2% (MAC 8.9).

The rapidity of onset of cardiovascular collapse in this case must be due to the following: 1) the high inspired concentration of isoflurane 10.2%; 2) the relatively low blood-gas partition coefficient of isoflurane (1.4 at 25° C); 3) controlled ventilation; and 4) presence of an anesthetic concentration of enflurane prior to the exposure to 10.2% isoflurane. The successful resuscitation was due to rapid detection and to maintenance of pulmonary and systemic blood flow with CPR and hyperventilation with 100% oxygen until the alveolar concentration of isoflurane could be decreased. The low blood-gas partition coefficient of isoflurane was beneficial at this point also, allowing a more rapid recovery than one might have seen if an agent with a higher coefficient had been used.

Although there is no substitute for vigilance, this particular mishap could have been prevented if an indexed pin safety system had been in use as suggested

by Munson over a decade ago.¹ The American National Standard Institute standard ANSI Z79.8 1979 (page 27, section 13.1.11) indicates that "the filling mechanism should be fitted with a permanently attached, standard, agent-specific keyed filling device to prevent accidental filling with the wrong agent." This standard is as stated a "should" standard rather than a "shall" standard, so that machines in use that do not contain such a device are not in violation of the standard. It should be noted that the Canadian Standards Association standard Z168.4-1975 requires a keyed device.

In summary, this case demonstrates that the hazards of agent-specific vaporizers are not merely theoretic. An indexed pin safety filling system should be a required standard on all agent-specific vaporizers.

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Perioperative Complications of Percutaneous Ultrasonic Lithotripsy of Renal Calculi

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Percutaneous ultrasonic lithotripsy of obstructive, symptomatic, or infected renal calculi is a recently developed surgical technique that has less perioperative morbidity and mortality than the standard renal pelvis surgery used to remove such calculi.¹⁻³ After 1,200 such procedures performed under general anesthesia at our

institution, there has been only one death, which was from an acute myocardial infarction that occurred on the second postoperative day following an uncomplicated procedure. In addition, there have been six life-threatening complications in the immediate postoperative period. Four patients had acute congestive heart failure develop and two others became hemodynamically unstable, presumably secondary to gram-negative sepsis. All six of these occurred in our first 400 patients.

Common to the evolution of many surgical techniques, there may be an initial high morbidity or mortality that decreases with improved surgical or anesthetic skill and patient selection. With the spreading introduction of this surgical technique and its initial use by many urol-

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ogists, complications similar to those experienced by our patients may be encountered. We present two cases representative of such complications.

REPORT OF TWO CASES

Case 1: Acute Congestive Heart Failure. A 62-year-old, 65-kg woman with a large staghorn calculus in her right renal pelvis underwent percutaneous ultrasonic lithotripsy following percutaneous placement of a wire into the renal pelvis under local anesthesia. Her medical problems included hypertension controlled with nadolol and chlorthalidate and a mild, untreated glucose intolerance. The physical examination and preoperative laboratory evaluation were normal. General anesthesia was induced with thiopental 350 mg iv and maintained with 50% nitrous oxide and 0.5 to 1.5% enflurane in oxygen following endotracheal intubation facilitated by succinylcholine 60 mg iv. The patient was placed in the prone position and received 1.3 l D₅ lactated Ringer's solution during the procedure.

At the completion of the 70-min procedure, 2.1 l of the sterile normal saline used for continuous renal irrigation during the lithotripsy had not returned, suggesting possible intravascular or extravascular extravasation. In addition, the abdominal wall was tense and the legs discolored, suggesting extravascular extravasation of fluid and venous congestion of the lower extremities. The patient had remained stable throughout the procedure and was transported to the recovery area with spontaneous ventilation while inhaling oxygen via the endotracheal tube.

Ten minutes postoperatively, the patient had expiratory wheezing develop. Bilateral moist rales and prolonged expiratory wheezes were apparent on auscultation. There were fluffy bilateral infiltrates on chest roentgenogram. Five minutes later, a moderate amount of pink, frothy fluid was present in the endotracheal tube, accompanied by hypotension with systolic blood pressures of 75–90 mmHg and sinus tachycardia. Treatment consisted of controlled ventilation with 5 cm positive end-expiratory pressure, furosemide 20 mg iv, and morphine sulfate 6 mg iv. A pulmonary artery catheter with oximetry was introduced. The pulmonary capillary wedge pressure was 25 mmHg with a mixed venous saturation of 62%. Within 30 min there was a diuresis of 1,100 ml urine, concomitant with improvement of hemodynamics, ventilation, and oxygenation. Extubation of the trachea was possible within an hour, and the patient had an uneventful postoperative course and was discharged on the fifth postoperative day.

Case 2: Gram-negative Sepsis. A 72-year-old, 86-kg man with a history of recurrent calcium oxalate renal calculi underwent a left renal percutaneous ultrasonic lithotripsy for a staghorn calculus following percutaneous placement of a wire into the renal pelvis under local anesthesia. His medical problems included recurrent urinary tract infections secondary to the calculi, insulin-dependent diabetes mellitus, and peptic ulcer disease. The physical examination and preoperative laboratory evaluation were normal except for urine cultures that grew proteus species. A three-day course of appropriate antibiotics was given prior to surgery. General anesthesia was induced with thiopental 350 mg iv and maintained with 50% nitrous oxide and 1–2% isoflurane in oxygen following endotracheal intubation facilitated by succinylcholine 100 mg iv. The patient was placed in the prone position and received 1.0 l D₅ lactated Ringer's solution and 0.8 l lactated Ringer's solution iv during the procedure. Blood glucose was estimated by Chemstrip® every 30 min and was stable at 120–180 mg/dl. During the procedure, the irrigation saline was blood tinged, but there did not appear to be a large hemorrhage. Vital signs remained stable during the 85-min procedure. At com-

pletion, the patient was turned supine and transported to the recovery area with spontaneous ventilation while inhaling oxygen via the endotracheal tube.

Five minutes postoperatively, mottling of the head and extremities was noted, concomitant with hypotension (60/45 mmHg), tachycardia (130 bpm), and tachypnea (40 breaths/min). The return of blood-tinged saline irrigation, blood in the urine, and these hemodynamic parameters suggested hemorrhage, although there was no visual evidence of gross bleeding. Initial therapy consisted of 1 l D₅ lactated Ringer's solution iv, Trendelenberg positioning, controlled ventilation with oxygen, and ephedrine 15 mg iv. This therapy resulted in only a slight increase in arterial blood pressure (75/55 mmHg). With controlled ventilation at F_IO₂ 1.0, P_aCO₂ was 90 mmHg, P_aCO₂ 31 mmHg, pH 7.25, base excess -12 mEq/l, HCO₃⁻ 10 mEq/l, and Sa_O₂ 95%. Hemodynamics did not continue to improve with iv fluid infusion, as would be expected from hypovolemia, therefore, systemic and pulmonary artery catheters were inserted. The pulmonary capillary wedge pressure was initially 3 mmHg, cardiac index 6.4 l·min⁻¹·m⁻², and systemic vascular resistance 550 dynes·s·cm⁻⁵. These indicated sepsis as the cause of hemodynamic instability. Further resuscitation included intravascular volume expansion, correction of acidosis with sodium bicarbonate, and infusion of dopamine at 5–8 µg·kg⁻¹·min⁻¹. Within 30 min, vital signs improved and the patient subsequently was placed in an intensive care unit. Twelve hours later, following initiation of appropriate antibiotic therapy, vital signs stabilized, inotropic support gradually was withdrawn, and the trachea was extubated. Blood and urine cultures were negative. The remainder of the hospital stay was uneventful, and the patient was discharged home on the eighth postoperative day.

DISCUSSION

This report demonstrates the initial high rate of morbidity that commonly can occur early in the evolution of a new surgical technique. Refinement of technique and patient selection obviously can alter outcome significantly. There were six life-threatening perioperative complications in our first 400 patients. Four patients developed acute congestive heart failure secondary to hypervolemia following retroperitoneal extravasation of saline irrigating solutions. We now accurately assess irrigating volume input and output via suction and Foley catheter drainage. This simple alteration can forewarn of extravasation and has prevented further intravascular fluid overload. Two patients became septic postoperatively after rapid ultrasonic dissolution of large, infected calculi, despite a preoperative 3-day course of appropriate antibiotics. Such calculi are now gently and slowly dissolved, with care to avoid intrarenal bleeding and the possible introduction of infected particles into an opened vessel. Since taking these precautions, there have been no such complications in the last 800 patients. In the future, it would be desirable to sterilize the urine preoperatively; however, at this time, it is impossible because the inside of the infected stone cannot be sterilized.

Certainly, there may be other complications. Bennett *et al.*⁴ described a sudden intraoperative cardiac arrest

during renal percutaneous ultrasonic lithotripsy. They speculated on four possible causes: 1) hypervolemia; 2) acute hyponatremia from irrigation with sterile water; 3) acute hemolysis and hyperkalemia secondary to a bolus of hypotonic irrigating fluid; and 4) air embolism. Hyponatremia and hypotolemia are not problems if saline irrigation fluids are used. Unlike transurethral resection of a prostate, avoidance of electrical conductivity is not an important consideration. Air embolism is possible with patients in a jack-knifed or laterally flexed position. To minimize this possibility, our patients are level in a prone position, leaving little, if any, gradient from the surgical site to the right atrium. Hemorrhage in the immediate perioperative period has not been a major problem. The percutaneous tract can be easily occluded and bleeding tamponaded.

In summary, we have described the major perioper-

ative complications of 1,200 patients undergoing percutaneous ultrasonic lithotripsy of renal calculi and the simple adaptations we have made to decrease morbidity. With the introduction and initial use of this surgical technique by many urologists, anesthesiologists involved in the care of patients undergoing such procedures should be aware of these possible complications.

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