

Hazards of Agent-specific Vaporizers: A Case Report of Successful Resuscitation after Massive Isoflurane Overdose

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The potential hazards of agent-specific vaporizers are primarily related to the accidental introduction of a volatile anesthetic into a vaporizer calibrated for a different agent. In one case, fluroxene was mistakenly placed in a vaporizer designed for diethyl ether.¹ This resulted in a long anesthesia induction time because the vapor pressure of fluroxene is only half that of diethyl ether. This is a case report of the opposite, potentially lethal use of an anesthetic (with a relatively high vapor pressure) in a vaporizer designed for an anesthetic with a low vapor pressure agent.

REPORT OF A CASE

A 50-kg, 41-year-old woman with a diagnosis of right ureteral obstruction with hydronephrosis was scheduled for a ureteronecystostomy under general anesthesia. The patient was in otherwise good health, and was ASA class I. She had several previous experiences under general anesthetics without complications. Her preoperative laboratory data included a hematocrit of 41.7%, BUN 7 mg/dl, creatinine 0.9 mg/dl, normal serum electrolyte levels, and normal electrocardiogram.

The anesthesia machine used for this case was an Ohio DM5000®, which uses vaporizers heated to 24°C ± 1°C to achieve direct-metering vaporization. This particular machine had only recently been put back into use due to the recall of the Foregger 705® machines because of a possible defect in the halothane vaporizer. This DM5000® machine still had a methoxyflurane vaporizer on the extreme right side, unlike all other DM5000® machines in the hospital that had the methoxyflurane vaporizers replaced with isoflurane units. The methoxyflurane label on the knob that engages the vaporizer was partially worn away, revealing only the letters "rane" on one side of the knob. In setting up for the case, the right side vaporizer was empty and was subsequently filled with isoflurane.

The preoperative arterial blood pressure was 120/90 mmHg, heart rate 80 bpm, and temperature 37°C. Induction of general anesthesia proceeded with *d*-tubocurarine 3 mg, thiopental 275 mg, succinylcholine 100 mg iv, and endotracheal intubation. Maintenance of anesthesia was accomplished with oxygen 40%, nitrous oxide 60%,

enflurane 1-2%, and pancuronium 2 mg iv. The vital signs remained very stable with arterial blood pressure of 100/70 mmHg and heart rate 70 bpm.

After 3 h of uneventful anesthesia, the initial anesthesiologist was relieved by another who believed that, due to the history of extrinsic renal disease, the anesthetic agent should be switched from enflurane to isoflurane. The enflurane vaporizer was turned off, and the far right vaporizer was turned on with a supposed output of 50 ml of isoflurane vapor and 5,000 ml total gas flow, or "1% isoflurane." After only a few breaths of isoflurane emanating from the methoxyflurane vaporizer, the patient immediately became cyanotic, had no palpable blood pressure, and no peripheral pulses by Doppler. The electrocardiogram showed an initial sinus tachycardia that changed progressively to bradycardia until no electrical activity could be detected.

Cardiopulmonary resuscitation (CPR) and appropriate drug treatment was begun immediately; the vaporizer and nitrous oxide were turned off. The anesthesia circuit was flushed with oxygen 100%; the patient was hyperventilated and responded rapidly. Thirty minutes after the arrest, the arterial blood pressure was 110/70 mmHg with a heart rate of 100 bpm.† The patient was given fentanyl 100 µg iv, lorazepam 2 mg iv, and nitrous oxide 50% for anesthesia. The ureteronecystostomy was completed 1 h and 45 min after the cardiac arrest was reversed. The patient was taken to the recovery room with stable vital signs. Three hours postarrest, the patient was responding to verbal commands, and the postoperative ECG had returned to normal. LDH and CPK isoenzymes showed no evidence of myocardial infarction. On the seventeenth postoperative day, the patient was discharged with no recall of any intraoperative events and no sequelae as a result of her cardiac arrest under anesthesia.

DISCUSSION

Intermixing of halothane, enflurane, and isoflurane has been examined both mathematically and experimentally.² The worst possible result of interchanging these three agents in an agent-specific vaporizer would be to put the agent with the highest vapor pressure into a vaporizer designed for the agent with the lowest vapor pressure, *i.e.*, putting halothane (vapor pressure 243 mmHg at 20°C) into an enflurane (vapor pressure 175 mmHg at 20°C) vaporizer. For example, if the enflurane vaporizer was adjusted to deliver enflurane 2%, it would actually be delivering halothane 3.21% (four times MAC).

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† At the time of the arrest, the surgery had progressed to the point that it had to be completed.

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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