and monitored with an apnea monitor for at least 12 h postoperatively. In our institution we found that herniorrhaphy can be safely performed in infants greater than 44 weeks conceptual age who do not have major cardiac, neurologic, endocrine, or metabolic diseases. Until more information is available, the care of a high-risk infant should be individualized and should remain conservative. Should any questions arise, postoperative monitoring and observation in a hospital setting are recommended.

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# A Cause of Breathing System Leak during Closed Circuit Anesthesia

PHILLIP J. FERDERBAR, M.D.,* ROBERT E. KETTLER, M.D.,† JAMES JABLONSKI, P.E., C.C.E.,‡
RICHARD SPORTIELLO, B.S.‡

Closed-circuit anesthesia requires meticulous attention to the anesthetic system. We recently observed a complication of closed-circuit anesthesia related to the injection of liquid anesthetic that resulted in equipment failure.

## Report of a Case

A Draeger Narkomed® anesthesia machine with a standard circle absorber system was prepared for closed-circuit use by inserting an injection port coupler (Anesthesia Associates, Inc., San Marcos, CA) into the breathing circuit. This coupler was equipped with a stopcock, a female Luer® connector, and a 25-gauge needle allowing for injection of liquid anesthetic agents into the lumen. The coupler was attached to the machine end of the expiratory limb hose. The flow-sensing cartridge of an electronic volume monitor (Ohmeda, Madison, WI, Model 5400) was attached to the other end of the coupler, and the flow cartridge was then attached to the inlet to the expiratory valve. A calibrated polarographic oxygen analyzer (Instrumentation Laboratories, Lexington, MA, Model 402) was used with the sensor placed in the dome of the expiratory valve. The entire system was checked for leakage of gases, and fresh gas flowmeters were properly calibrated prior to the induction of anesthesia.

A healthy, 35-yr-old, 96-kg man presented for elective ankle exploration and removal of fractured bone fragments. Medical and surgical history as well as physical examination, vital signs, review of systems, chest radiograph, ECG, and routine laboratory studies were within normal limits.

Following breathing of 100% oxygen for 5 min and use of conventional monitoring, anesthesia was induced with *d*-tubocurarine, 3 mg iv, and thiopental, 700 mg iv. Endotracheal intubation was facilitated by succinylcholine, 100 mg iv. Correct location of the endotracheal tube was confirmed by auscultation.

* Resident in Anesthesiology.
† Assistant Professor in Anesthesiology.
‡ Clinical Engineer.

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Address reprint requests to Dr. Kettler: Department of Anesthesiology, Milwaukee County Medical Complex, 8700 West Wisconsin Avenue, Milwaukee, Wisconsin 53226.

Key words: Equipment: anesthesia; circuits; machines.

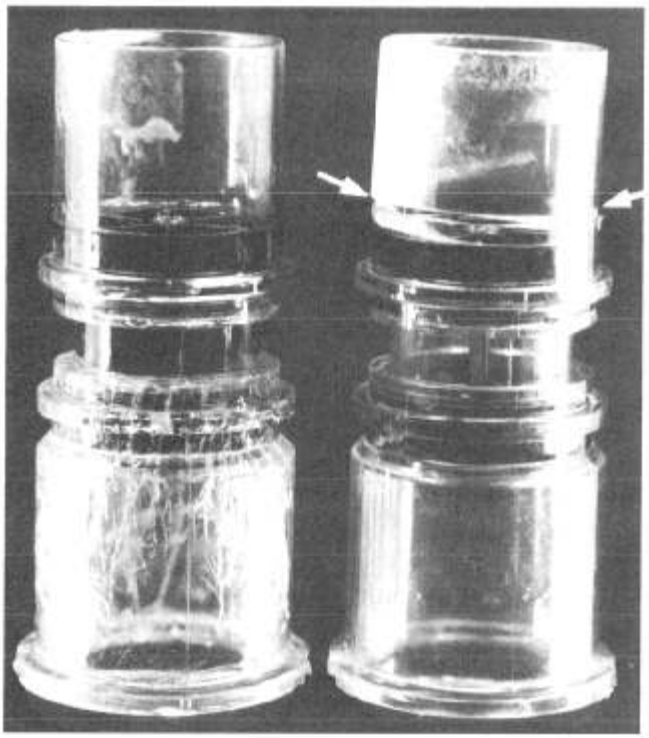

FIG. 1. The cartridge on the *right* was damaged during the case described. Note the spiral crack (*arrow*) about one-third of the way from the top. The cartridge on the *left* was immersed in liquid halothane for five min.

Total fresh-gas flow was then reduced to 500 cc/min, and the popoff valve was closed, with close attention paid to the expiratory-limb oxygen tension, which remained stable at 30–32 volume %. The breathing bag volume likewise remained stable following equilibration of the patient with nitrous oxide. A prime dose of 0.6 ml of liquid halothane was then given through the injection port in the expiratory limb, with subsequent maintainance doses of 0.6 ml given (at 1, 4, 9 min, and so forth) according to the "square-of-time" method.[1]

Following the administration of the fourth dose of liquid halothane, the patient became tachypneic (respiratory rate of 30 breaths/min), and the volume in the breathing bag decreased suddenly, indicating a large leak within the breathing circuit. Expiratory oxygen tension continued to indicate 30–32 volume %. The patient subsequently began swallowing and manifesting other signs of inadequate anesthesia including moderate increases in heart rate (from 76 to 110 beats/min) and arterial blood pressure (from 105/60 to 145/95 mmHg) as well as movement. Inspection of the breathing circuit revealed a large leak of gases at the junction of the expiratory volumeter cartridge and metallic injection port coupler; the volumeter cartride was grossly distorted in shape. Both of these devices were then removed with some difficulty due to fusion of the plastic with the metal port of the anesthesia machine. Thereafter, the breathing circuit proved acceptably leak free. The remainder of the anesthetic was provided by semiclosed circle system with $CO_2$ absorber using an out-of-circle halothane vaporizer. The patient recovered and was discharged uneventfully.

## DISCUSSION

In a closed-circuit anesthetic all fresh gas flow is from the anesthesia machine and there is no gas vented from the breathing circuit.[2] If a leak develops, these conditions are no longer fulfilled and the patient's inspired gases can become diluted by room air. It is unclear if the level of anesthesia was inadequate because of dilution of the inspired anesthetic, or because a stable plane of anesthesia had not yet been obtained because of time constraints. Presumably the duration of leak was short because the only change noted in the system was a volume loss from the rebreathing bag and not a change in expired concentration. However, depending on the resistance to flow through the cartridge, the patient could have been inhaling from and exhaling to the atmosphere. In this case, the $O_2$ analyzer would be exposed to a static sample and will not reflect true circuit conditions.

The large spiral defect depicted in the right cartridge in figure 1 occurred when the volumeter cartridge was removed from the breathing circuit. We propose that the initial leak was a quite small one when the volumeter flow cartridge was partially dissolved and weakened.

The cartridge in use was the TVX® flow cartridge (Ohmeda) made of polysulfone (Udel P-1700, Union Carbide, Somerset, NJ) and was chosen by the volumeter manufacturer because of mechanical strength (tensile strength, yield = 70.3 MPa; flexural strength, yield = 106.2 MPa)[3] stiffness, and clarity.§ It has also been approved by the Food and Drug Administration for gas sterilization and chemical disinfection.§

Cracking on a molecular scale is not well understood, but presumably a chemical bond under stress fails. This results in an increase in stress on other bonds; consequently, the crack can propagate. A polymer resists cracking because of the net effect of all covalent and noncovalent bonds. However, these bonds can be disrupted by various solvents. Polysulfone's resistance to solvent degradation has been rated as poor for partially halogenated hydrocarbons, ethers, and phenols; although the commonly used volatile agents and thymol had previously not been tested, they would presumably be similarly effective solvents.[4] As stated in the *International Plastics Selector,* poor resistance means that "the use of the plastic in the presence of the indicated agent is not recommended. The effect varies from a catastrophic failure (such as dissolution) to a severe degradation (such as cracking) which results in a sufficient loss of integrity that the plastic is unacceptable for even a short time."¶

To further investigate the effects of the common potent inhalational anesthetics on the TVX® flow cartridge, we immersed three cartridges in baths of halothane, enflurane, and isoflurane individually. The flow cartridge im-

§ G. Schroeder, Personal Communication, Ohmeda, January 22, 1986.

¶ *The International Plastics Selector Extending and Molding Guides.* San Diego, Calkobrin, 1977, pp 717, 720–721.

merse in halothane (*left*, fig. 1) underwent dissolution to the extent depicted in 5 min. The cartridges immersed in isoflurance and enflurane appeared undamaged to a cursory inspection after 48 h, but cracking was apparent on close inspection.

Communication with Ohmeda revealed that most plastics are disrupted to some extent by immersion in liquid agents, but that they have good resistance to disruption on exposure to the vapors of the three commonly used agents. Ohmeda does not recommend use that would involve immersion.§

Because of this incident we recommend that one of two precautions be taken during closed-system anesthesia using the injection technique: 1) The TVX® flow cartridge should be placed upstream of the injection port, so that anesthetic agent does not pool on it. A possible arrangement is to place the flow cartridge between the Y-piece and the expiratory tubing. As long as the flow detector of the volumeter is placed appropriately for the direction of the expiratory flow, the flow cartridge can be inverted and still function. 2) Alternatively, the flow cartridge could be omitted and another technique of measuring ventilatory volume chosen.

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# Anesthetic Management of Cesarean Section in a Patient with Idiopathic Hypertrophic Subaortic Stenosis

REMIGIO V. BOCCIO, M.D.,* JAMES H. CHUNG, M.D.,† DEBORAH M. HARRISON, M.D.†

Idiopathic hypertrophic subaortic stenosis (IHSS) is a disease characterized by obstruction to left ventricular outflow secondary to hypertrophy of septal myocardium just beneath the aortic valve. The stiff, hypertrophied muscle mass leads to diastolic dysfunction as well as systolic obstruction; this is manifested as congestive heart failure (with exertional dyspnea and easy fatigability), dysrhythmias, and sudden death. Inheritance is autosomal dominant, with initial presentation of symptoms in childhood or young adulthood.

Obstruction to left ventricular outflow by the hypertrophic myocardium may be affected by several of the physiologic alterations occurring in pregnancy and during labor. The hypervolemia associated with pregnancy can improve circulatory dynamics. However, any decrease in preload, as would occur in blood loss, supine positioning (with aortocaval compression by the uterus), and the Valsalva maneuver, could increase left ventricular outlet obstruction by making the left ventricular cavity smaller. The consequent decrease in cardiac output could compromise uterine blood flow. During labor and delivery, catecholamine release secondary to pain, fear, and anxiety can increase the inotropic state of the myocardium, thereby increasing subvalvular stenosis.

Reports,[1,2] of cesarean deliveries in these patients have failed to define their anesthetic management; therefore, we are reporting the results of such a case.

## Report of a Case

A 26-yr-old primagravida, with known twin pregnancy at 32 weeks gestation, was admitted with possible toxemia of pregnancy and premature cervical dilation and effacement.

Ten years prior to admission, IHSS was diagnosed by cardiac catheterization and ultrasound. (These were performed at another hospital and the results were unavailable to us.) She was receiving propranolol 40 mg po qid, and, because of ventricular tachycardia noted on ambulatory electrocardiographic monitoring approximately 1 yr earlier, was also being treated with procainamide 750 mg po qid. Past surgical history was remarkable only for strabismus surgery and tonsillectomy in childhood which were uncomplicated. Family history revealed two brothers with IHSS who died suddenly in young adulthood.

The patient was asymptomatic on admission. Physical examination revealed an arterial blood pressire of 112/60 mmHg. The lungs were clear. Cardiac examination revealed normal first and second heart sounds. There were no third or fourth heart sounds. A grade 3/6 systolic ejection murmur was audible at the left lower sternal border and a grade 3/6 holosystolic murmur was heart at the apex. The ankles

* Resident Physician.
† Assistant Professor.
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Address reprint requests to Dr. Boccio (current address): State University of New York at Stony Brook, Health Sciences Center, Stony Brook, New York 11794.

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