

Chronic Exposure to Anesthetic Gases in the Operating Room

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Halothane present in the ambient atmosphere was continuously measured in each of two operating rooms during the conduct of surgical anesthesia. Concentrations were determined on-line with a mass spectrometer and found to vary with sampling site, breathing system used, and the scavenging system employed to remove overflow anesthetic gases. Concentrations of halothane measured within a 3-foot radius of the anesthesia equipment averaged 8.7 ppm when a nonrebreathing circuit was used (flow 10 l/min), and 4.9 ppm with a semiclosed circle system (flow 4-5 l/min). End-tidal concentrations of halothane averaged 0.21 ppm in 81 samplings from operating room nurses and 0.46 ppm in 36 samplings from anesthetists. Residual concentrations were present in many individuals 16 hours after exposure. A significant reduction in atmospheric contamination of the operating room was obtained by use of appropriate scavenging equipment. The implications of these findings are discussed. (Key words: Anesthetics; Operating room contamination; Chronic toxicity; Halothane; Operating room ventilation.)

SEVERAL RECENT STUDIES have called attention to the presence of trace concentrations of anesthetic gases in the operating room atmosphere and indicated a potential hazard to personnel chronically exposed.¹⁻⁷ A number of devices which attempt to reduce this contamination have been constructed.⁸⁻¹⁰ Using a quadrupole mass spectrometer § capable of measuring halothane (and other anesthetic gases) in ranges from 50 ppb to 100,000 ppm, we conducted a comprehensive survey of halo-

thane concentrations in the operating room and in end-tidal samples obtained from anesthetists and nurses. Anesthetic gas scavenging systems were also developed and tested in an attempt to reduce atmospheric contamination and exposure of personnel. The results of these investigations constitute the subject of this report.

Methods

Concentrations of halothane were determined in each of two selected operating rooms during the course of the daily surgical schedule. Atmospheric halothane was sampled through a length of polyethylene tubing placed at nine different locations chosen to reflect those concentrations rebreathed in the immediate area of the anesthesia machine. Additional samples were obtained from four distant locations (fig. 1). On subsequent days, excess anesthetic gases were removed by means of scavenging systems and repeat analyses made. The sampling of halothane was provided by a quadrupole mass spectrometer which generated on-line data at a response time of one second with an inlet flow rate of 3.5 l/min.¶ The halothane molecule was identified at mass unit 117.

The two operating rooms studied measured 3,940 and 4,930 cubic feet and were air-conditioned without recirculation at flow rates of 650 and 700 cubic feet/min, respectively. This provided a total air exchange once every 6-7 minutes, and waste air was vented to the outside. Ventilation inflow was located near ceiling level, and the outflow was six inches from floor level on an adjacent wall. All analyses were obtained over a 30-second sampling time and were repeated at half-hourly

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§ System Q30 Process Sampler, UTI, Sunnyvale, Calif.

¶ Specifications include: resolution, 400 at mass 200; sensitivity, 100 amps/torr; mass range, 1 to 200 Amu.

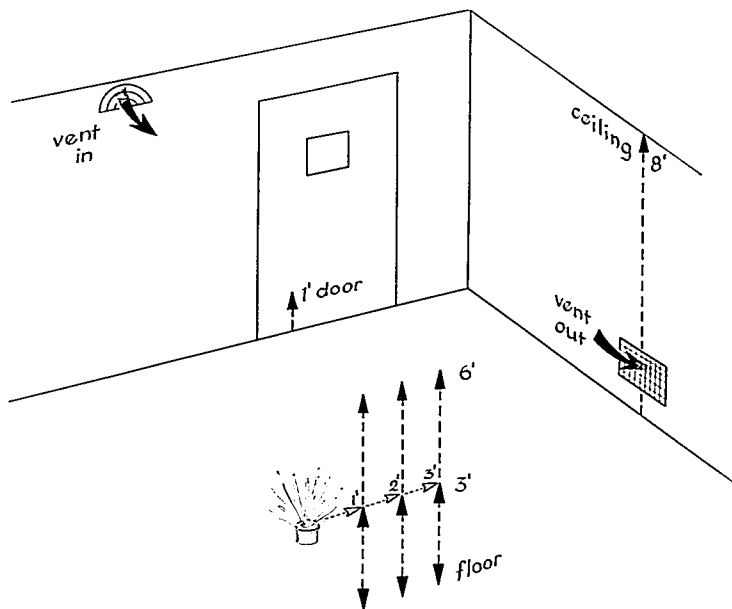


FIG. 1. Sampling sites for halothane are indicated by solid arrows. The catheter was held at each site for approximately 30 seconds, and all sites were sampled at 30-minute intervals throughout the day.

intervals. Sampling was carried out at prescribed times regardless of the activities of either the operating room or the anesthetist.

To compare the two techniques most commonly used for anesthetic administration, analyses were performed separately with a nonrebreathing system (Lewis-Leigh valve), and a semiclosed circle filter system (Heidbrink). On alternate days, overflow anesthetic gases were removed by scavenging equipment. In all systems, 1 per cent halothane was administered together with nitrous oxide and oxygen.** With the nonrebreathing system, flow rate was maintained at 10 l/min, and with the circle system at 4 to 5 l/min. For the scav-

enged nonrebreathing system, a 3-liter reservoir bag was closely fitted to the exhalation port and the tail of the bag attached to wall suction via a "T piece" open to room air. The scavenging system for the partial rebreathing circuit captured overflow gases in a collector system and conducted them to wall suction (fig. 2). A one-way valve prevented excessive negative pressure from developing within the rebreathing circuit, and the suction-control valve was adjusted to keep the reservoir bag partially collapsed.

End-tidal concentrations of halothane of nine anesthetists (36 samples) and 27 operating room nurses (81 samples) were measured at intervals throughout the day. A control sample was obtained from each individual early in the morning prior to work in the op-

** On study days, halothane and N₂O were the only general anesthetic agents used, although operations under local or regional anesthesia were interspersed among the others.

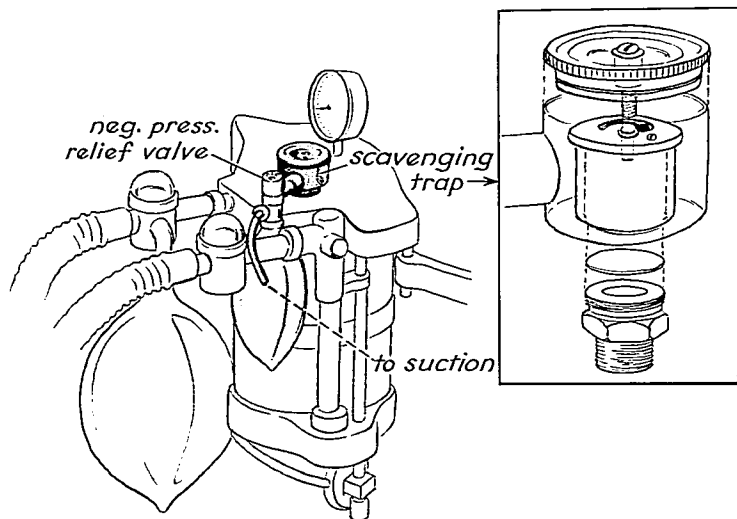


FIG. 2. The scavenging system used for the semiclosed circle system. Inset shows details of the trap which replaces the standard "pop-off" valve. The scavenging system is connected to suction, and excess negative pressure is prevented by inflow of room air through the negative-pressure relief valve.

erating room. Samples were also obtained at the end of the day. The studies imposed no restraint on the normal daily routine, which permitted nurses and anesthetists to move freely into and out of the operating suite.

Results

Although concentrations of halothane in the operating room atmosphere were usually below detectable levels at the beginning of the day, measurable concentrations were obtained within minutes after the beginning of anesthesia regardless of the breathing circuit used. Table 1 lists halothane concentrations at the test points during each of the four test conditions, *i.e.*, unscavenged nonbreathing, scavenged nonbreathing, unscavenged semiclosed circle and semiclosed circle with scavenging.

Table 2 summarizes data comparing halothane concentrations in the operating room during the use of a nonbreathing system and a semiclosed circle system, with and without

scavenging equipment. Mean concentrations of halothane sampled throughout the day within a 3-foot radius of the exhalation port are shown. The scavenging system was capable of reducing mean concentrations of halothane in the operating room atmosphere by 91 per cent with the nonbreathing system and by 85 per cent with the semiclosed circle system.

Validity of the end-tidal gas samples obtained from operating room personnel was defined at frequent intervals through appearance of a waveform characterized by a deadspace washout and a slowly rising plateau near the end of exhalation, followed by a quick return to zero with inhalation. Control values for the nurses, determined early in the morning prior to exposure to halothane, averaged 0.01 ppm. During the work day these rose to an average of 0.21 ppm (table 3). The anesthetists had initial end-tidal halothane concentrations of 0.08 ppm, rising to a mean of 0.46 ppm during the course of the work day.

End-tidal halothane levels greater than 1.0 ppm were found in six samples from the anesthetists and in samples from one nurse.

Discussion

The present investigation confirms earlier studies, indicating a residual concentration of anesthetic gases in the operating room during the course of anesthesia. Measurable concentrations were found throughout the operating room atmosphere and afforded exposure to all personnel. End-tidal samples from operating room personnel contained measurable halothane concentrations 16 hours after exposure. Significant atmospheric pollution with anesthetic gases is obviously present in the operating room, and represents a potentially serious problem. Although a definitive health hazard has not been identified, the following previously reported studies may be applicable.

Animals chronically exposed to low concentrations of halothane or methoxyflurane (0.1 MAC) had weight losses, hepatomegaly, and histologic changes in the liver.¹¹ Rats exposed to lower concentrations of halothane (100 ppm) did not show pathologic changes.¹² A comparison of halothane metabolism in anesthetists vs. pharmacists suggests a higher rate of metabolism in the former, presumably due to microsomal enzyme induction by chronic exposure to halothane vapor.¹³ Recent studies in twins, however, emphasize the importance of genetic factors in this biotransformation.¹⁴ Sensitization to halothane in patients and anesthetists has been authenticated.¹⁵⁻¹⁷ Hepatic damage was shown to follow repeated halothane anesthetics in the former, and minimal re-exposures to halothane in the latter. Headache following halothane anesthesia has been found to be a common complaint of patients, possibly attributable to the direct effects of the agent on the brain or the cerebral vessels.¹⁸ Similar complaints from anesthetists have been reported.^{4,7} A survey of Russian anesthetists indicates an increase in "functional disturbances of the central nervous system" following prolonged exposure to poorly ventilated operating rooms.⁷ A recent study reports the incidence of death from malignancies of the lymphatic and reticuloendothelial systems to be slightly higher in a small sample of anesthesiologists than in the general

TABLE 1. Ambient Halothane Concentrations under the Four Test Conditions*

	Sampling Level 6 feet			Sampling Level 3 feet			Floor			Ceiling	Vent Out	Vent In	Door
	1 Foot from Inhalation Port	2 Feet from Inhalation Port	3 Feet from Inhalation Port	1 Foot from Exhalation Port	2 Feet from Exhalation Port	3 Feet from Exhalation Port	1 Foot from Exhalation Port	2 Feet from Exhalation Port	3 Feet from Exhalation Port				
Number of samples	11	11	11	11	11	11	11	11	11	11	11	11	11
Number of samples (with 100% sensitivity)	11	11	11	11	11	11	11	11	11	11	11	11	11
Mean (ppm)	1.25	0.78	0.70	0.20	0.28	0.29	0.20	0.19	0.30	0.51	0.44	0.40	0.30
Standard deviation (ppm)	0.40	0.20	0.20	0.08	0.11	0.11	0.20	0.10	0.30	0.15	0.12	0.10	0.10
Standard error (ppm)	0.12	0.06	0.06	0.03	0.03	0.03	0.06	0.03	0.09	0.04	0.04	0.03	0.03
95% confidence interval (ppm)	0.80-1.70	0.50-1.00	0.50-0.90	0.10-0.30	0.15-0.45	0.15-0.45	0.05-0.35	0.05-0.35	0.05-0.55	0.35-0.65	0.25-0.65	0.25-0.55	0.20-0.40
99% confidence interval (ppm)	0.50-2.00	0.30-1.30	0.30-1.10	0.00-0.40	0.00-0.50	0.00-0.50	0.00-0.40	0.00-0.50	0.00-0.60	0.15-0.85	0.05-0.80	0.05-0.75	0.00-0.60

* Sensitivity of the sampling system was 100% for concentrations of 0.1 ppm or greater. The detection limit was 0.1 ppm.

TABLE 2. Mean Combined Concentrations of Halothane Determined at 1-, 2-, and 3-foot Perpendiculars to the Exhalation Port and at 0- through 6-foot Levels*

	Ppm Halothane (\pm SE)	Per Cent Reduction
Nonbreathing system		
No scavenging	8.69 \pm 0.91	—
With scavenging	0.79 \pm 0.15	91
Semiclosed circle system		
No scavenging	4.93 \pm 0.96	—
With scavenging	0.73 \pm 0.10	85

* Samples ($n = 423$) collected at 30-minute intervals.

TABLE 3. Mean End-tidal Concentrations of Halothane in Nurses (81 Samples) and Anesthetists (36 Samples), before and during Daily Work Schedule

	Initial Halothane Concentration (ppm \pm SE)*	Mean Halothane Concentration during Work Day (ppm \pm SE)
Nurses ($n = 27$)	0.01 \pm 0.006	0.21 \pm 0.04
Anesthetists ($n = 9$)	0.08 \pm 0.03	0.46 \pm 0.07

* Samples taken prior to re-exposure to operating room atmosphere. There was usually a time lapse of 16 hours between exposure periods.

population, with a possible relationship to toxicity of the inhaled anesthetics.¹⁹ Finally, evidence for the teratogenicity of many inhalation anesthetic agents has been shown in the experimental animal.²⁰⁻²⁷ This is of particular concern because an increased spontaneous abortion rate in female doctors and nurses has been suggested in certain preliminary reports.^{6, 28} Additional evidence for this observation is presented separately.²⁹

Thus, it appears that the chronic exposure of operating room personnel to trace concentrations of anesthetics offers a theoretical hazard. One might ask what is the safe level for anesthetic gases in the operating room atmosphere. This is difficult to define. At the present time, threshold limit values (TLV) have been established for only two anesthetic agents,^{††} and these levels do not take into

consideration recent information about metabolism, enzyme induction, or teratogenicity.³⁰ In the face of a potential hazard, and with only limited data available, it would seem prudent to establish these levels at minimum values for the new fluorinated anesthetics, and possibly revise downward those previously established for the older anesthetics.

Present studies suggest the practicability of maintaining ambient halothane in the operating room atmosphere below a concentration of 1 ppm. Reduction of this contamination to the lowest possible level should be attempted. Our present recommendations are that operating rooms be air-conditioned with non-circulating systems capable of providing minimal total air exchange rates of at least 10 times per hour. Such systems may be expected to significantly reduce, although not totally eliminate, the contaminating anesthetic gases. In addition, when high-flow anesthetic systems are employed, arrangements should be made for closed-system venting of all excess gases to the outside through the use of appropriately designed scavenging equipment.^{‡‡} Only with this combined approach can we hope to clean the operating room air of trace anesthetic contaminants adequately. By adopting these relatively simple and effective measures, we will move towards the elimination of a potentially serious hazard to those working in the operating room.

†† Chloroform, 50 ppm; diethyl ether, 400 ppm. These guidelines were established by the American Conference of Government Industrial Hygienists (A.C.G.I.H.) in 1967. Concentrations represent time-weighted averages reflecting conditions under which it is believed that workers may be repeatedly exposed without adverse effect. These values are only suggested guides for the control of health hazards and do not consider the wide range of individual susceptibilities.

‡‡ The wall suction system used for scavenging in this study has the disadvantage of being intermittently needed for patient care. Presently, we are funneling excess anesthetic gases directly into the exhaust ducts of the room ventilation system. This necessitates an air-conditioning system without recirculation and a low-resistance ($\frac{1}{8}$ inch) wall outlet. Such an arrangement has another important advantage, in that it eliminates the hazard present in certain commercial scavenging systems which may transfer maximum wall suction pressure directly to the patient's lungs.

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