U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45202

HEALTH HAZARD EVALUATION DETERMINATION
REPORT NO. 75-22-228

HOLYOKE HOSPITAL
HOLYOKE, MASSACHUSETTS

OCTOBER 1975

I. TOXICITY DETERMINATION

An environmental survey was conducted on April 23-25, 1975 in the operating rooms at Holyoke Hospital to determine concentrations of waste anesthetic gases and vapors to which operating room personnel were being exposed. The potential toxicity of waste inhalation anesthetic gases has been demonstrated in animal experiments and epidemiological studies. Present technology does not allow anesthetic gases to be completely eliminated from operating room air without compromising safe anesthetic administration practices. However, the potential health hazard can be minimized by ensuring that specific work practices be followed to reduce leakage of gases, and by establishing scavenging techniques to collect and dispose of waste anesthetic gases. It has been reported that concentrations of 30 ppm nitrous oxide and 0.5 ppm halothane are achievable during the routine use of inhalation anesthetics. It has been demonstrated that environmental concentrations of halothane and nitrous oxide measured in the operating rooms at Holyoke Hospital greatly exceed these levels, and recommendations for effective control of these gases are included herein.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this determination report are available upon request from Hazard Evaluation Services Branch, NIOSH, U.S. Post Office Building, Room 508, 5th and Walnut Streets, Cincinnati, Ohio 45202. Copies have been sent to:

a) Holyoke Hospital, Holyoke, Massachusetts
b) U.S. Department of Labor - Region I
c) NIOSH - Region I

For the purposes of informing the approximately 30 "affected employees" the employer will promptly "post" the Determination Report in a prominent place(s) near where exposed employees work for a period of 30 calendar days.

III. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) authorizes the Secretary of Health, Education, and Welfare, following a written request by an employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The National Institute for Occupational Safety and Health received such a request from the Administrator of Holyoke Hospital regarding exposure of operating room employees to waste anesthetic gases in the operating rooms. At the time that the survey request was generated, there were no alleged health problems in any of the operating room personnel. However, recent epidemiological studies have provided evidence that exposure of operating room personnel to anesthetic gases is a health hazard. Therefore, a request was made to determine "the extent, and possible effects, of waste anesthetic gases in the operating rooms."

IV. HEALTH HAZARD EVALUATION

A. Conditions of Use

Holyoke Hospital is a 310-bed hospital built in 1893. The surgical suite, added in 1957, has five operating rooms. There is an adjoining recovery room and a cystoscopy room nearby. Approximately 20 nurses and 10 members of the Anesthesiology Department work in the operating rooms; the exact number differs according to variations in the operating room schedule. The operating rooms are generally in use for eight hours each day as well as for emergency surgical procedures.

Five categories of operating room personnel may be present during an operation: the surgeon, the anesthetist (which may be an anesthesiologist or a nurse anesthetist), scrub nurse, circulating nurse, and surgical technician. There are usually four to seven people on the surgical team, depending on the type of operation being performed. Their principal source of exposure to waste anesthetic gases is leakage from the anesthesia equipment. Halothane, nitrous oxide, and cyclopropane are the general anesthetic agents which are currently in use at Holyoke Hospital. Cyclopropane is used very rarely, halothane is used in approximately 50 percent of all surgical cases in which general anesthesia is used, and nitrous oxide is used in about 80 percent of the cases.

There is a great deal of variation in the amount and type of exposures received by operating room personnel. Procedures may last from 15 minutes to several hours and the amount of anesthesia gases used varies with the type and duration of the operation, as well as with the individual anesthetist. In most instances where general anesthesia is given, a combination of nitrous oxide and halothane is used. On occasion, cyclopropane is used in place of halothane at Holyoke Hospital.

The anesthetic circuit is composed of the anesthesia machine and the breathing system. Nitrous oxide and oxygen are piped in from outside the operating room at controlled flow rates. Halothane, which is a liquid halogenated hydrocarbon, is vaporized in the anesthesia machine to form a mixture in the range of 0.75 to 2% halothane with oxygen. The concentration is varied during an operation - a higher concentration is used during induction than during maintenance of anesthesia. Nitrous oxide (combined with oxygen in equal volume proportions) and halothane are combined before entering the breathing circuit. Whereas all of the anesthetists at Holyoke Hospital used a flow rate of 2 liters per minute of the halothane-oxygen mixture, the flow of nitrous oxide/oxygen usually varied from 2 to 4 liters per minute.

The breathing system consists of a soda lime canister (to absorb exhaled carbon dioxide), breathing bag, valves for assuring unidirectional gas flow, flexible hoses, and a Y-piece terminating in an endotracheal tube or face mask. The anesthetic mixture is delivered at a rate greater than the patient's metabolic need. The breathing bag fills, and the excess gases are vented out of the breathing system through the pop-off valve. The volume of gases and vapors escaping through the pop-off valve is highly variable, as it is dependent on the patient's breathing pattern and metabolic rate. The pop-off valve is the major source of leakage of anesthetic gases; other sources are the face mask or endotracheal tube, cracks or holes in the hoses, through fittings or seals, or from spilled liquid halothane. Since anesthetic gases are eliminated through the lungs, recovery room personnel could be exposed to nitrous oxide and halothane from the patients' exhaled air.

The concentrations of anesthetic gases to which operating room personnel are exposed may be dependent on their proximity to the anesthesia machine and, to a lesser extent, to air currents in the room. The anesthesiologist or nurse anesthetist sits or stands closest to the anesthesia system. The surgeon may also be very close to the system, depending on the operation. The nurses and technicians generally move about the room more freely. Fresh air is brought into each room at the ceiling level and exhausted from a wall or ceiling vent at a rate of 15 to 20 air changes per hour. The ventilation system is separate from that of the rest of the hospital. There is no local ventilation control or scavenging system for the waste anesthesia gases.

B. Evaluation Design

A preliminary observational survey of the operating rooms was conducted on April 23, 1975 by a team of four NIOSH industrial hygienists. During the following two days, personal breathing zone and general area samples were obtained for halothane, nitrous oxide, and cyclopropane. An average of four employees per operating room, including the anesthetist and surgeon in almost all cases, wore Sipin pumps and charcoal tubes. Wherever feasible, the tubes were changed after each operation. The exposures of recovery room nurses were similarly monitored. The charcoal tubes were analyzed for halothane by gas chromatography at the Analytical Research Laboratories, Inc., in Monrovia, California. The results of these analyses are presented in Table 1.

Concentrations of nitrous oxide were determined in the field with a Wilks Miran I infrared analyzer. Samples of air, representative of personal breathing zone exposures of attending anesthesiologists, were collected in 30-liter Mylar bags via a 3-foot length of Tygon tubing attached to MSA Model G pumps adapted for bag filling. The bag was removed after each operation, capped, and a new bag was attached. Area samples for nitrous oxide analysis were also collected in the hallway of the surgical suite and in the recovery rooms. The nitrous oxide concentrations are presented in Table 1.

Bag samples were analyzed usually within minutes after collection. Analyses were performed at a wavelength of 4.48 microns and a path-length of 8.25 meters unless otherwise noted in the table of results.

C. Evaluation Criteria

1. Toxicologic Effects

Until recently, nitrous oxide was considered to be a simple asphyxiant without other significant physiologic effects. No standard has been set for occupational exposure to halothane either. Both of these chemicals have been selected for use in surgical procedures because of their abilities to produce narcosis or unconsciousness in sufficient concentrations. Much less is known about the effects of subanesthetic concentrations. Animal experiments, epidemiologic studies, and a recent NIOSH investigation are now providing evidence that chronic exposure to low concentrations of inhalation anesthetics may be a health hazard.

The teratogenic effects of nitrous oxide have been demonstrated in developing chicks and rats when pregnant animals were exposed to nitrous oxide in anesthetic concentrations.[1,2] Other animal experiments have shown the embryotoxicity in the rat of chronic exposure to low concentrations of nitrous oxide.[3] Nitrous oxide has also been associated with hematopoietic effect, including leucopenia and bone marrow depression.[4]

Halothane has similarly been shown to have teratogenic effects on developing chick embryos.[1] Subanesthetic halothane exposures have produced increased liver:body weight ratios and centrolobular hepatic fatty metamorphosis in other toxicologic experiments.[5,6]

Cyclopropane is generally considered to be an effective anesthetic agent with few post-operative complications. However, its use has been phased out in many hospitals because it is extremely explosive. It is most frequently used when halothane anesthesia is contraindicated.

There is also evidence from human exposures that anesthetic agents are potentially toxic. Since other halogenated hydrocarbons are known to be capable of producing liver damage, the hepatotoxicity of halothane has undergone comprehensive review. A committee on Anesthesia of the National

Academy of Sciences-National Research Council reviewed several reports associating halothane anesthesia with post operative hepatic necrosis, but concluded that this was limited to certain hypersensitive individuals and that the actual incidence was very low.[7]

Epidemiological studies have also provided evidence on the toxicity of nitrous oxide and halothane. Increased incidences of headaches, fatigue, irritability, spontaneous abortion, and abnormal pregnancies were reported in a study of Russian anesthesiologists who used primarily nitrous oxide and ether.[8] Obstetric histories were obtained from 563 married women anesthetists and 828 women physician controls in the United Kingdom. It was determined that anesthetists working during pregnancy had an increased ratio of spontaneous abortions to live births and an increased frequency of congenital abnormality in live births. Women anesthetists also had a higher incidence of infertility than the control group.[9] The most comprehensive study was conducted by the American Society of Anesthesiologists Ad Hoc Committee on Effects of Trace Anesthetic Agents on Health of Operating Room Personnel.[10] Questionnaires were mailed to 49,585 exposed operating room personnel and 23,911 control persons. The exposed and unexposed groups were compared to determine whether there were important differences in occurrence rates of spontaneous abortions, congenital abnormality rate, cancer rate, hepatic disease rate, and renal disease rate. Spontaneous abortion rates were found to be higher among women working in the operating room than in comparable unexposed women. The congenital abnormality rate was found to be higher both for exposed women and for wives of exposed men than for their unexposed counterparts. Exposed women were also found to have an increased risk of developing cancer and renal disease than the control groups. Both male and female operating room personnel had significantly higher frequencies of hepatic disease than unexposed groups. Although it was recognized that other variables could account for these increased risks in disease rates, it was concluded that the exposure to waste anesthetic gases in the operating room was the probable cause.[10]

2. Environmental Standards

Since there are insufficient data to correlate exposure concentrations to toxic effects, no standard limiting exposure to waste anesthetic gases has yet been put into effect. Exposure guidelines have therefore been formulated based on limiting exposure through technology designed to remove the waste gases and vapors from the operating room environment. A group of professors from Stanford University, working under a NIOSH contract, evaluated methods for eliminating waste anesthetic gases and vapors.[8] They concluded that effective control of the waste gases could reduce concentrations to less than 30 ppm of nitrous oxide and less than 0.5 ppm halothane during the routine use of inhalation anesthetics. No specific recommendation was made for exposure to cyclopropane, however, a general reduction of inhalation anesthetics to 0.005 percent of the concentration administered to the patient was considered to be a reasonable guideline. Cyclopropane concentrations measured at Holyoke Hospital on April 25 should therefore be no higher than approximately 15 ppm.

D. Evaluation Results and Discussion

Results of environmental sampling are presented in Table 1. The concentrations of nitrous oxide measured at Holyoke Hospital ranged from less than 5 ppm to approximately 6000 ppm. Only 3 of 27 measurements were below the recommended level of 30 ppm and the median value was 525 ppm. The lowest levels were found in the recovery room. The highest concentration, 6000 ppm, occurred during a procedure in which nitrous oxide was the only general anesthetic used and the nitrous oxide:oxygen ratio was increased to 5:2. Concentrations exceeding 2000 ppm were recorded four times when the usual anesthetic gas mixtures were given.

Halothane concentrations were also generally higher than the NIOSH recommendation of 0.5 ppm - breathing zone concentrations ranged from "none detectable" to 21.3 ppm. The average halothane concentrations found in the operating rooms (excluding the recovery room) were 3.40 ppm on April 24 and 3.73 ppm on April 25.

With air exchange rates of 15-20 per hour, the general distribution of waste gases in the operating room would be expected to be fairly uniform except within 1 or 2 feet of a source of leakage. The anesthetist, and in many cases, the surgeon would be standing in closest proximity to the anesthesia system and therefore to the major leak sources. The data does indicate that surgeons and anesthetists were usually exposed to higher concentrations than the nurses; nonetheless only 5 of the 67 breathing zone samples collected in the operating rooms were less than 0.5 ppm halothane and three of these were obtained during surgical procedures in which no halothane was used. The exposures of recovery room nurses to halothane were also monitored and all concentrations were found to be below the recommended level.

Cyclopropane was detected on front and back sections of the two charcoal tubes connected in series for all samples. The values recorded therefore represent the minimum concentrations to which the monitored personnel were exposed. The surgeon was exposed to a minimum of 1.51 ppm and the nurse anesthetist was exposed to a minimum of 8.14 ppm cyclopropane. Four recovery room nurses were monitored and their exposures were found to be between 0.001 to 0.3 ppm as minimum values.

E. Conclusions and Recommendations

Environmental data indicate that operating room personnel at Holyoke Hospital are exposed to concentrations which could have potentially toxic effects. Since there are no defined "safe" levels of exposure, personnel exposure must be limited by the application of control measures including scavenging of gases at the anesthesia machine, "low leakage" practices by the anesthetist, and equipment maintenance.

The air conditioning system is non-recirculating and the general room ventilation appeared to be sufficient. Therefore, a simple scavenging program would collect the waste gases at the points of leakage, especially the pop-off valve and dispose of them into the exhaust grille of the non-circulating air conditioning system. An alternative is to dispose of the gases in the central vacuum system. All scavenging components must be gastight.

While the ventilator is in use, the pop-off valve on the anesthesia machine would be closed. Therefore the ventilator must have a waste gas collector. Existing ventilators can be converted for scavenging or new units may be purchased.

Equipment maintenance and servicing will also reduce anesthetic leakage. Breathing hoses, bags, gaskets, and seals should be routinely checked. Procedures for leak testing can be found in the NIOSH publication, Development and Evaluation of Methods for the Elimination of Waste Anesthetic Gases and Vapors in Hospitals. Also included in this publication are specific brand names and details on components of scavenging systems, suggestions for air monitoring, and low-leak work practices for the anesthetist.

V. REFERENCES

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TABLE 1

Concentrations of Waste Anesthesia Gases in Operating Rooms at Holyoke Hospital

April 24, 1975

Room	Sample Period	Surgical Procedure	Anesthesia Used*	Job Title	Halothane (ppm)	Nitrous Oxide (ppm)
207	8:00 - 9:30	Rt. subman-	N_2O:Halothane	Nurse anesthetist	1.51	425
	8:00 - 9:30	dibular gland	= 2.5:2	Surgeon	0.93	
	8:00 - 9:37	resection		Circulating nurse	0.58	
	8:00 - 9:30			Scrub nurse	0.51	
207	9:50 - 11:00	Exc bunion,	N_2O:Halothane	Nurse anesthetist	15[1]	525
		IP fusion of	= 2.5:2	Circulating nurse	2.14	
		metatarsal		Scrub nurse	2.28	
		left head				
209	8:00 - 10:00	Bronch	N_2O:Halothane	Anesthesiologist	1.14	410
	9:00 - 9:35	& CME	= 2:2	Surgeon	0.99	
	8:00 - 10:10			Circulating nurse	1.26	
	8:00 - 10:15			Scrub nurse	0.83	
	8:00 - 10:15			Scrub nurse	0.33	
209	10:50 - 11:55	Laparoscopy	N_2O:Halothane	Anesthesiologist	8.18	550
	10:15 - 11:50		=2:2	Circulating nurse	1.22	
	10:15 - 11:45			Scrub nurse	0.13	
	10:15 - 11:50			Scrub nurse	0.75	
211	8:00 - 8:50	Maxillary	N_2O:Halothane	Anesthesiologist	> 2.74	10
	8:50 - 10:00	Vestiboplasty	= 4:2	Anesthesiologist		2000[2]
		& exc.epulis		Surgeon	4.23	
				Circulating nurse	1.13	
				Scrub nurse	2.0	
211	10:00 - 11:25	4 impactions	N_2O:Halothane	Anesthesiologist	9.49	2500[2]
	9:59 - 11:34		4:2	Surgeon	4.06	
	10:05 - 11:25			Dental internist	4.08	
	9:57 - 11:41			Circulating nurse	0.72	

TABLE 1 (contd)

Room	Sample Period	Surgical Procedure	Anesthesia Used*	Job Title	Halothane (ppm)	Nitrous Oxide (ppm)
211	11:50 - 12:45	9 extractions	N_2O:Halothane	Nurse anesthetist	17.7	2300[2]
	12:05 - 12:45	- 1 Alveo		Surgeon	17.0	
	11:41 - 12:45			Circulating nurse	4.22	
	12:08 - 12:45			Scrub nurse	14.8	
214	8:50 - 9:46	D & C with	N_2O:Halothane	Nurse anesthetist		2200[2]
	9:15 - 9:46	biopsy cervix		Surgeon	3.91	
	8:53 - 9:46			Circulating nurse	2.94	
	8:47 - 10:03			Scrub nurse	2.34	
214	9:45 - 10:30	Exc breast	N_2O:Halothane	Nurse anesthetist	3.77	600[3]
	10:00 - 10:35	cyst		Circulating nurse	1.40	
214	11:20 - 12:25	Full mouth	N_2O:Halothane	Nurse anesthetist	4.69	510
	11:34 - 12:20	extraction		Surgeon	9.09	
	11:25 - 12:20			Dental internist	2.04	
	11:35 - 12:25			Circulating nurse	3.12	
Recovery Room	9:25 - 12:55			RN	<0.01	< - 10
	9:25 - 12:20			RN	0.11	
	9:25 - 12:55			RN	0.11	
	12:20 - 2:13			RN	<0.01	
	12:20 - 2:13			RN	<0.01	
	12:55 - 2:13			RN	<0.01	
	12:55 - 2:13			RN	<0.01	
236	8:20 - 8:35	Cystoscopy	N_2O:Halothane	Anesthesiologist		220[3]
Hall Outside	9:42 - 10:52					90
214	10:52 - 12:27					75
			April 25, 1975			
207	8:10 - 9:20	Repair	N_2O:Halothane	Anesthesiologist	6.25	700
	8:10 - 9:15	Strabismus -		Surgeon	7.05	
	7:55 - 9:20	rt. eye		Circulating nurse	1.96	
	7:55 - 9:35			Scrub nurse	6.78	

TABLE 1 (contd)

Room	Sample Period	Surgical Procedure	Anesthesia Used*	Job Title	Halothane (ppm)	Nitrous Oxide (ppm)
207	11:30 - 12:15	Left ilial	N_2O:Halothane	Anesthesiologist	6.46	1600[2]
	11:15 - 12:30	femoral		Circulating nurse	1.24	
	11:20 - 13:40	bypass		Scrub nurse	1.94	
	11:30 - 13:40	graft		Scrub nurse	0.65	
209	8:15 - 8:52	Cysto with	N_2O:Halothane -	Nurse anesthetist	11.4	750
	8:17 - 8:50	stone	1.25%	Circulating nurse	3.57	
	8:20 - 8:52	removal		Scrub nurse	1.33	
209	8:55 - 10:58	Tutty Plott	N_2O:Halothane	Nurse anesthetist	0.99	725
	9:15 - 10:53	procedure -		Surgeon	21.3	
	8:55 - 10:57	left		Circulating nurse	1.75	
	8:55 - 10:54	shoulder		Scrub nurse	1.64	
211	8:03 - 9:00	Extraction	N_2O:Halothane	Nurse anesthetist	>3.97	375
	9:00 - 9:57	of		Nurse anesthetist		
	8:07 - 9:49	impactions		Surgeon	4.82	
	8:08 - 9:50			Assistant surgeon	3.14	
	8:06 - 9:52			Circulating nurse	2.58	
211	9:55 - 10:58	Termination	$N_2O:O_2$	Nurse Anesthetist	1.48	6000[2]
	9:53 - 10:57	of pregnancy	= 3:1, + local	Circulating nurse	0.27	
211	11:05 - 12:25	I & D	N_2O:Halothane -	Nurse Anesthetist	3.26	750[2]
	10:58 - 12:20	axillary	1.5%	Circulating nurse	3.0	
	11:18 - 12:20	abcess		Scrub nurse	3.77	
214	8:00 - 11:36	Evacuation	N_2O:cyclopropane	Circulating nurse	<0.01	25
	8:12 - 11:23	clot-leg & exploratory laparotomy	= 1:0.4	Scrub nurse	<0.01	
215	7:55 - 8:50	Release of	N_2O:Halothane	Nurse Anesthetist	5.40	325
	8:05 - 8:48	left tibial		Surgeon	3.03	
	7:55 - 8:50	tendon		Circulating nurse	2.71	
236	8:00 - 10:15	cystoscopy	N_2O:Halothane	Nurse	0.14	

TABLE 1 (contd)

Room	Sample Period	Surgical Procedure	Anesthesia Used*	Job Title	Halothane (ppm)	Nitrous Oxide (ppm)
Hall Outside	9:37 - 10:05	N.A.				90
211	10:06 - 10:20					60
Recovery Room	9:16 - 12:27	N.A.		RN	<0.01	
	9:15 - 12:27			RN	<0.01	
	8:45 - 12:43			RN	0.09	
	8:45 - 12:43			RN	<0.01	

* Ratios given, where known
1 Estimated from short-term sample
2 Concentrations approximated from operation of Wilks Miran I at a pathlength of 0.75 meters
3 Approximate concentration, bag exhausted prior to attainment of equilibrium in cell