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CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

HEALTH HAZARD EVALUATION DETERMINATION
REPORT NO. 76-113-385

ENGLEWOOD HOSPITAL
ENGLEWOOD, N. J.

APRIL 1977

I. TOXICITY DETERMINATION

A Health Hazard Evaluation was conducted by the National Institute for Occupational Safety and Health (NIOSH) in the operating room, recovery room, and delivery room areas of the Englewood, N.J., Hospital. On November 15-17, 1976, environmental samples were collected to determine the concentration of nitrous oxide, halothane, and enflurane in these areas.

Findings of this evaluation indicate that the mean exposure of anesthesiologists to nitrous oxide was 160 ppm, and to halogenated anesthetic was 1.4 ppm. The average exposure of nurses to halogenated anesthetic was 0.4 ppm. These concentrations exceed the NIOSH recommended limit of 25 ppm nitrous oxide and 0.5 ppm halogenated anethetic. Since information on adverse health effects due to exposure to waste anesthetic gases is not completely definitive and many unknown factors still exist, recommended permissible levels of exposure are not defined as safe levels but rather as levels which are attainable with current technology. These levels should prevent the effects caused by acute exposure and significantly reduce the risk associated with long term, low level exposure.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Technical Services, Information and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office at the Cincinnati address.

Copies of this report have been sent to:

a. Englewood Hospital, Englewood, New Jersey
b. Englewood Hospital Professional Nursing Association
c. U.S. Department of Labor, Region II
d. NIOSH, Region II

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 a representative of the Englewood Hospital Professional Nurses Association regarding exposure of personnel to waste anesthetic gases in the operating room, recovery room, and delivery room areas.

There were no specific alleged health problems at the time the request was generated. The recognition of the potential health hazard associated with chronic exposure to anesthetic gases was primarily responsible for the health hazard evaluation request.

IV. HEALTH HAZARD EVALUATION

A. Process Description

Anesthetic gases were used in nine operating rooms and two delivery rooms in Englewood Hospital on the days of this survey. Exposure to those gases was also suspected in the recovery room, hallways and adjacent areas. The anesthetics were nitrous oxide and either halothane (2-bromo-2-chloro-1,1, 1-trifluoroethane) or enflurane (2-chloro-1,1,2-trifluoroethyl difluoromethyl ether).

The anesthetic circuit is composed of the anesthesia machine and the breathing system. The anesthesia machine vaporizes the potent anesthetic (halothane or enflurane) and combines it with nitrous oxide and oxygen, which are pumped to the machine from outside the room or supplied from cylinders affixed to the machine. The breathing system consists of a soda lime canister (to absorb entailed carbon dioxide), breathing bag or ventilator, valves for assuring unidirectional gas flow, flexible hoses, and a "Y" piece terminating in an endotracheal tube or face mask.

The anesthetic gas mixture is delivered at a rate higher than the patient's metabolic needs. When a breathing bag is used, 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 are highly variable since it depends on the patient's breathing pattern and metabolic rate. When a ventilator is in use the pop-off valve on the anesthetic machine is closed and the ventilator assumes the function of the pop-off valve. As the system is now designed, the pop-off valve and the ventilator are the major sources of waste anesthetic gas.

Other sources are the face mask or endotracheal tube, cracks or holes in the hoses, tube fittings or seals, or from spilled liquid anesthetic.

B. Evaluation Design

A preliminary observational survey of the areas was conducted on November 15, 1976, by a team of NIOSH industrial hygienists. During the following two days, breathing zone and general area air samples were obtained for halothane, enflurane, and nitrous oxide. The breathing zone samples were obtained by attaching sampling equipment to operating room and delivery room personnel. Anesthesiologists were sampled during operating room procedures whenever they were willing to wear the equipment, which consisted of charcoal tube sampler for halothane and enflurane, and a bag sampler for nitrous oxide. Some charcoal tube samplers were placed on other operating room personnel. Identical sampling equipment was also placed in the recovery room, hallways and adjacent areas. The charcoal tubes were shipped to a laboratory for analysis by gas chromatography and bag samples were analyzed on site by infrared spectrophotmetry. A more detailed description of the sampling and analytical methods can be found in Health Hazard Evaluation Determination Reports 75-22-228 and 75-76-232.

C. Evaluation Criteria

In a criteria document for a recommended standard for occupational exposure to anesthetic gases (1), NIOSH states: "Current scientific evidence obtained from human and animal studies suggests that chronic exposure to anesthetic gases increases the risk of both spontaneous abortion among female workers and congenital abnormalities in the offspring of female workers and the wives of male workers. Risks of hepatic and renal diseases are also increased among exposed personnel. In addition, physiological function may be impaired. A few studies have suggested increased risk of cancer. Effects on the central nervous system due to acute exposures of anesthetic gases have been associated with headaches, nausea, fatigue, irritability, etc." Control procedures and work practices presented in that document, however, should prevent the effects caused by acute exposure and significantly reduce the risk associated with long term, low level exposure. A dose response relationship for halogenated anesthetic toxicity has not been defined.

Reports by Visman (8) and Askrog and Harvald (9) were among the first to identify increased incidents of spontaneous abortion in women exposed to anesthetic gases and in wives of men exposed to anesthetic gases. Results of a more recent and comprehensive nationwide survey of occupational disease among operating personnel were published in 1974 by American Society of Anesthesiologists (ASA) (2). The results of this study indicate "that female members of the operating room-exposed group were subject to increased risks of spontaneous abortion, congenital abnormalities in their children,

cancer and hepatic and renal disease. This increased risk of congenital abnormalities was also present among the unexposed wives of male operating room personnel. No increase in cancer was found among the exposed males, but an increased incidence of hepatic disease similar to that in the female was found."

While several investigators have reported increased rates of resorption in animals, particularly rats, most of these studies involved concentrations of anesthetic gases well above the levels found in occupational exposure. One investigator (19), however, showed increased fetal death rates in two groups of rats following exposure of 1,000 and 100 ppm of nitrous oxide. Doenicke et al (18) concluded from their study of anesthetized pregnant rats that halothane demonstrates an abortive effect directly proportional to the concentration inhaled, again referring to anesthetic concentrations, but nitrous oxide does not produce an abortive effect. Bruce (20) reports no significant difference, including implanatations and resorptions per pregnancy, in his exposure of rats to 16 ppm of halothane.

Several epidemiological studies that indicate increased spontaneous abortions also indicate an increased rate of congenital abnormalities. The ASA study (2), as well as surveys by Knill-Jones et al (10) and Corbett et al (11) indicated an increased rate of congenital abnormalities in children of women with occupational exposures to anesthetic gases, and to wives of men with similar exposures. While most animal exposures studies have been conducted at anesthetic levels, one study (15,16,17) indicated liver, kidney, and brain tissues changes in pups born to rats exposed to sub-anesthetic concentrations of halothane during pregnancy.

The same epidemiological and toxicological studies that indicated an increase in spontaneous abortion and congenital abnormalities also indicated an increase in liver and kidney abnormalities. This increase however, was less pronounced in both rate and severity.

In a study published by NIOSH, (7) "nitrous oxide and halothane in respective concentrations as low as 50 parts per million (ppm) and 1.0 ppm, caused measurable decrements in performance on some psychological tests taken by healthy male graduate students. Nitrous oxide alone caused similar effects. The functions apparently most sensitive to these low concentrations of anesthetics were visual perception, immediate memory, and a combination of perception, cognation and motor responses required in a task of divided attention to simultaneous visual and auditory stimuli." Headache, fatigue, irratibility, and disturbance of sleep have also been reported (8,12); and damage to cerebral cortical neurons has been seen in rats after subanesthetic exposure to halothane (14). Quimby et al (13) reported permanent learning deficits in rats exposed to anesthetic concentrations of halothane during early development (from conception).

Mortality and epidemiological studies have raised the questions of possible carcinogenicity of anesthetic gases but sufficient data are lacking to list nitrous oxide, halothane or enflurane as suspected carcinogens.

Literature reviews regarding halothane (4,5,6,21) indicate the most widely accepted mechanism of bio-transformation is the production of trifluoro-acetic acid with resulting urinary excretion of trifluoroacetic acid and bromide. The literature regarding enflurane (3,22) does not indicate any one accepted mechanism, but increased serum and urinary fluoride levels were found in patients receiving enflurane anesthesia. While epidemiological and toxicological studies have indicated several symptoms apparently related to sub-anesthetic exposure to anesthetic gases, no cause and effect relation-ship has yet been shown.

D. Evaluation Results

Results of environmental sampling are summarized below. This table shows the individual anestheologist's exposure to both nitrous oxide (N_2O) and to a combination of the halogenated anesthetics halothane and enflurane (H+E). Concentrations shown are time weighted averages for all samples, and are expressed in parts of contaminant per million parts of air (ppm). Similar results are shown for scrub nurses, circulating nurses, and delivery nurses as groups.

Subject	No. of Samples		Sampling Time Hour/minute		Time Weighted Average Concentrations/ppm	
	N_2O	H + E	N_2O	H + E	N_2O	H + E
Dr. #1	6	3	2/35	4/55	80	1.0
Dr. #2	5	3	2/25	4/15	260	3.1
Dr. #3	7	5	4/15	6/10	120	1.0
Dr. #4	4	3	2/25	8/50	210	2.8
Dr. #5	6	3	3/0	4/55	180	2.7
Dr. #6	5	3	1/45	4/30	120	1.8
Dr. #7	-	1	-/--	2/40	---	2.3
Dr. #8	1	-	0/35	-/--	330	---
Scrub Nurses	-	6	-/--	20/50	---	0.5
Circ. Nurses	-	9	-/--	31/20	---	0.4
Del. Nurses	-	3	-/--	7/15	---	0.2

Results of all environmental samples are grouped by location and presented in Table 1 at the end of this report. From this table it can be seen that single samples ran as high as 800 ppm for nitrous oxide and 7.6 ppm for halothane.

E. Summary and Conclusions

Findings of this evaluation indicate that the average exposure of anesthesiologists to nitrous oxide was 160 ppm, with a range of 80 to 330 ppm; and to halogenated anesthetic was 1.4 ppm, with a range of 0.2 to 3.1 ppm. The average exposure of nurses to halogenated anesthetic was 0.4 ppm. The estimated exposure of nurses to nitrous oxide was 30-50 ppm. This estimate is based on concentrations of N_2) found in operating rooms and on the N_2O : (H+E) ratios of the anestheologists.

Time weighted average exposures, as presented in Section D, were calculated only for the time during which the anesthetists or nurses were wearing the sampling equipment. For the anesthesiologists this averaged approximately 4 hours out of 16 (two 8 hour working days). While these averages represent what is believed to be the maximum concentration periods, the total exposure was not measured. Due to the presence of waste anesthetic gases in all areas in appreciable quantities at almost all times, exposure during the remaining 12 hours may significantly add to the workers overall exposure.

While much statistical and toxicological evidence links exposure to waste anesthetic gases with various harmful effects, there is currently insufficient data available to accurately correlate any of these effects with exposure concentration except in the case where nitrous oxide is used alone. Audio visual decrement observed in exposed volunteers at 50 ppm nitrous oxide were not observed at 25 ppm nitrous oxide and 0.5 ppm of halothane. Based on this information, NIOSH recommends that where exposures are limited to nitrous oxide alone, the permissible levels of exposures should be 25 ppm.

No standard for any combination of nitrous oxide and halogenated anesthetic has been recommended on the basis of possible harmful effects. A cause and effect relationship has not been established through bio-transformation or other studies to indicate a basis for any observed effect. It is the opinion of NIOSH (1), however, that technology is available to reduce concentrations of nitrous oxide and halogenated anesthetic to 25 ppm and 0.5 ppm respectively when used in combination, and in so doing to prevent the effects caused by acute exposure and significantly reduce the risk associated with long term, low level exposure.

V. RECOMMENDATIONS

Several actions should be taken to reduce the concentration of waste anesthetic gas in the area of concern. These include scavaging, general exhaust ventilation, work practices, and equipment maintainence.

Scavaging equipment should be installed on anesthetic gas machines to collect waste gas which could be disposed of by local exhaust ventilation.

General exhaust ventilation should be provided in all areas where anesthetic gases are used, stored, or found to exist in perceptible concentrations. Recommended air exchange rates can be found in "Minimum requirements of construction and equipment for hospitals and medical facilities" (HEW Publication No. 74-4000, Rockville, Md. 1974).

Work practices should be reviewed and revised to assure minimum waste of anesthetic gases. One means to accomplish this is to reduce the flow to the patient. Some anesthesiologists feel this is a valid practice since the patient's metabolic rate requires only a fraction of the oxygen provided by currently popular techniques. Other anesthesiologists, however, feel that the excess of oxygen (and therefore of anesthetic gas, since all agree that the proportions should remain roughly constant) is necessary to provide a margin of safety. Other possible revisions in work practices, as stated in the criteria document on anesthetic gases (1), include:

1. Prior to the beginning of administration of an anesthetic agent, waste gas disposal systems shall be connected and proper operation determined.

2. If a face mask is to be used for administration of anesthetics, it shall provide as effective a seal as possible against leakage to the ambient air.

3. Vaporizers shall be filled in a ventilated area and in a manner to minimize spillage of the liquid agent. When feasible, vaporizers should be filled when the location where the anesthetic will be administered is not in use. The vaporizers shall be turned off when not in use.

4. Low pressure lead tests for the complete anesthetic machine shall be conducted daily.

5. Anesthetic gas flow shall not be started prior to induction of anesthesia.

6. When the breathing circuit is disconnected from the patient after administration of the anesthetic agent has started, anesthetic flowmeters shall be turned off or the y-piece sealed.

7. The breathing bag shall be emptied into the scavenging system before it is disconnected from the anesthetic delivery system.

Anesthesia equipment should be checked and maintained on a regular basis. Both high and low pressure components should be leak tested. Face masks, tubing, breathing bags and endotracheal tubes should be visually inspected for cracks and other leak sources.

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TABLE 1

Results of Samples for Nitrous Oxide, Halothane, and Enflurane
Grouped by Location

Englewood Hospital
Englewood, New Jersey

November 16-17, 1976

Location	Description	Day	Time	N_2O	Concentration (ppm) Halothane	Enflurane
OR 1	On Anesthesiologist #1	1	9:15 - 10:15	-	0.3	2.8
	On Circ. Nurse	1	10:45 - 12:45	-	ND	0.6
	" " "	1	12:10 - 1:55	-	ND	ND
	On Anesthesiologist #1	1	9:15 - 9:50	70	-	-
	" " "	1	9:50 - 10:15	85	-	-
	" " "	1	10:45 - 11:15	70	-	-
	" " "	1	11:15 - 11:40	90	-	-
OR 2	On Circ. Nurse	1	10:55 - 2:30	-	ND	0.4
	On Anesthesiologist #4	2	8:00 - 1:30	-	ND	0.1
	On Circ. Nurse	2	8:00 - 1:30	-	ND	0.2
	" " "	2	8:00 - 1:30	-	ND	0.2
	On Anesthesiologist #4	2	8:00 - 8:37	45	-	-
	" " "	2	8:38 - 9:20	25	-	-
OR 3	On Anesthesiologist #4	1	12:00 - 1:25	-	.1	ND
	" " #4	1	10:35 - 11:00	700	-	-
OR 3 & 4	On Anesthesiologist #4	1	10:35 - 11:08 (OR 3) 1:20 - 3:25 (OR 4)	-	7.6	ND
OR 4	On Anesthesiologist #2	1	9:12 - 9:41 10:24 - 12:00	-	2.8	1.7
	" " "	1	12:32 - 1:05	-	ND	1.3
	" " "	1	1:50 - 3:20	-	1.5	ND
	On Circ. Nurse	1	9:45 - 1:44	-	0.1	0.5
	" " "	2	12:30 - 2:30	-	.1	0.2
	On Scrub Nurse	2	8:10 - 2:30	-	.2	0.4
	On Anesthesiologist #2	1	9:12 - 9:41	800	-	-
	" " "	1	10:35 - 11:06	180	-	-
	" " "	1	11:07 - 11:34	30	-	-
	" " "	1	11:35 - 12:00	140	-	-
	" " "	1	12:32 - 1:05	120	-	-
	Area 6-8 ft. from Operating Table	1	1:20 - 2:25	35	-	-
	Area 6-8 ft. from Operating Table	1	2:25 - 3:00	55	-	-
	In OR between Procedures	1	1:00 - 1:20	ND	-	-
	In OR between Procedures	1	2:35 - 2:45	120	-	-
OR 5	On Scrub Nurse	2	12:30 - 3:10	-	ND	ND

*Indicates substane was not detected

TABLE 1 (cont.)

Location	Description	Day	Time	Concentration (ppm) N_2O	Halothane	Enflurane
OR 6	On Anesthesiologist #3	1	1:30 - 3:15	-	ND	0.7
	" " "	1	3:15 - 4:30	-	ND	1.8
	On Scrub Nurse	1	1:35 - 3:25	-	ND	0.9
	On Anesthesiologist #3	1	9:05 - 9:45	100	-	-
	" " "	1	1:30 - 2:10	70	-	-
	" " "	1	2:10 - 2:45	75	-	-
	" " "	1	2:45 - 2:55	>70	-	-
	" " "	1	3:15 - 3:55	90	-	-
	" " "	1	3:55 - 4:30	130	-	-
OR 7	Area 6-8 ft. from Operating Table	2	8:00 - 9:45	-	0.3	0.1
	Area 6-8 ft. from Operating Table	2	8:00 - 8:45	65	-	-
	On Anesthesiologist #6	2	9:50 - 10:15	110	-	-
	" " "	2	10:15 - 10:45	100	-	-
	" " #7	2	9:50 - 12:30	-	1.9	0.4
	" " #6	2	9:55 - 10:55	-	ND	1.0
OR 8	On Anesthesiologist #6	1	9:05 - 11:50	-	1.6	ND
	" " #3	1	9:10 - 9:45	-	1.1	ND
	" " #3	1	10:10 - 11:10	-	ND	0.5
	" " #5	1	9:20 - 10:00	-	2.3	ND
	" " #5	1	10:15 - 11:55	-	4.7	ND
	" " #5	1	1:55 - 4:30	-	1.4	0.1
	On Circ. Nurse	1	9:20 - 12:00	-	0.7	ND
	On Scrub Nurse	1	1:15 - 3:40	-	0.8	ND
	On Anesthesiologist #1	2	7:45 - 10:15	-	0.2	0.5
	On Circ. Nurse	2	7:50 - 12:10	-	0.1	0.3
	On Scrub Nurse	2	7:50 - 12:40	-	0.04	0.2
	On Anesthesiologist #5	1	9:20 - 9:55	160	-	-
	" " "	1	10:15 - 11:05	145	-	-
	" " "	1	11:05 - 11:55	210	-	-
	" " "	1	1:55 - 2:30	280	-	-
	" " "	1	2:30 - 3:20	160	-	-
	" " "	1	3:20 - 4:05	135	-	-
	" " #1	2	8:00 - 8:17	115	-	-
	" " "	2	8:37 - 8:55	60	-	-
Cysto	On Anesthesiologist #4	1	9:25 - 10:05	260	ND	5.7
	On Scrub Nurse	1	9:25 - 12:10	-	0.1	0.6
	On Anesthesiologist #6	2	10:50 - 11:35	-	3.4	ND
	" " "	2	10:55 - 11:07	100	-	-
	" " "	2	11:18 - 11:30	60	-	-
	" " "	2	1:15 - 1:40	210	-	-

TABLE 1 (cont.)

Location	Description	Day	Time	Concentration (ppm) N_2O	Halothane	Enflurane
Hall	Outside OR's 6 & 8	1	2:00 - 4:20	-	0.1	0.4
	" " "	1	2:00 - 2:55	35	-	-
	" " "	1	3:40 - 4:20	60	-	-
	" " 2	1	12:25 - 12:35	10	-	-
	" " 4 & 5	2	9:35 - 10:08	35	-	-
	" " 5	2	11:01 - 11:10	12	-	-
	" " 4 & 5	2	11:30 - 12:05	17	-	-
	" " 3	2	12:58 - 1:27	15	-	-
	" " 7 & 8	2	8:55 - 9:25	40	-	-
Recovery Room	Near S.E. Wall	1	10:30 - 3:20	-	0.1	0.3
	" " "	1	10:30 - 11:10	17	-	-
	" " "	1	11:55 - 12:55	20	-	-
	" " "	1	3:15 - 3:25	15	-	-
	" " "	2	1:45 - 2:00	20	-	-
Delivery	On Del. Nurse	2	7:15 - 10:30	-	0.2	ND
	" " "	2	7:15 - 10:30	-	0.2	ND
	" " "	2	7:30 - 8:15	-	ND	ND
	On Anesthesiologist #3	2	9:53 - 11:27	-	1.1	ND
	" " "	2	9:53 - 10:30	145	-	-
	" " "	2	11:00 - 11:27	270	-	-