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ABSTRACT

An evaluation of anesthetic waste gas exposures was conducted in small private practice animal clinics through-out the Salt Lake Valley. The two most frequently used anesthetic gases, methoxyflurane and halothane, were chosen to be studied. Exposures during 38 surgeries were studied in a total of 10 facilities involving 13 veterinarians. Veterinarian breathing zones were sampled on a real time basis with a Wilks Miran. Several back to back surgeries were also monitored to determine the potential for gas build-up in the operating rooms. The monitoring results indicated that veterinarians have a significant exposure to anesthetic gases. Time weighted averages over the anesthetic administration period ranged from 0.07 to 2.99 ppm for methoxyflurane and 0.08 to 9.19 ppm for halothane. A leak test was performed on each piece of anesthesia equipment. Of the 20 machines checked, 55 % did not meet the NIOSH recommendations concerning maximum leakage of 100 ml/min under 30 cm of water pressure. NIOSH further recommends that if leakage is greater than 1 liter/min the machines should not be used till repaired. Thirty per cent of the units inspected exceeded this value. The oxygen flowrate, which determines the amount of anesthetic agent used, was not a function of animal size. This practice resulted in an excessive use of anesthetic agent for small animals. The halothane concentrations were higher than the methoxyflurane concentrations because of the out of

circuit vaporizer design which requires higher oxygen flowrates. Overall, scavenging was found to be effective in reducing anesthetic gas exposures by 2.7 fold for methoxyflurane and 43 fold for halothane. However, during back to back surgeries a gradual build-up of anesthetic gas was found in the surgical rooms even with the use of scavenging equipment. This indicates a need for additional engineering controls. The use of a ceiling exhaust fan resulted in a 38 fold reduction in the exposure concentration. It appears that dilution air can provide effective control even for nonscavenged and poorly maintained anesthesia machines. It is recommended that a scavenging system along with good work practices and dilution ventilation be utilized to control anesthetic waste gas exposures in veterinary clinics.

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OCCUPATIONAL EXPOSURE OF VETERINARIANS TO WASTE ANESTHETIC GASES

May 7, 1987

BY: DAVID L. POTTS

THESIS COMMITTEE

CHAIRMAN: Dr BOBBY CRAFT

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Introduction

Chronic exposures to anesthetic gases have been reported to cause a variety of ill effects including spontaneous abortion [1-8], congenital abnormalities [3-5,7,9], infertility [6,7], renal disease [3], hepatic disease [3,4,7,8,10], cancer [3-5,7-9,11,12], and decreased motor and mental acuity function [7,13,14]. In addition, the inorganic fluoride ion which is the metabolic byproduct of methoxyflurane is well known to cause renal tubular necrosis.[14,15,16-19] Because anesthetic agents are highly lipid soluble, they are very slowly eliminated from the body taking days to even weeks for the agents to biodegrade in the body.[10,18,20] According to the National Institute for Occupational Safety and Health (NIOSH), an estimated 50,000 veterinarians and associated employees are potentially exposed to anesthetic waste gases.[21]

Standards

At the present, there are no permissible exposure limits (PELs) set by the Occupational Safety and Health Administration (OSHA) for anesthetic agents in use today. However, both NIOSH and ACGIH have recommended safe exposure levels. The NIOSH [21] recommended criteria is 2 parts per million (ppm) for halogenated agents (halothane, methoxyflurane, enflurane, and fluroxene) and 25 ppm for nitrous oxide when used alone. When nitrous oxide is used in conjunction with one of the halogenated agents, NIOSH contends the halogenated levels can be maintained below 0.5 ppm. NIOSH also recommends daily leak testing of all anesthesia equipment. With the breathing circuit pressurized to 30 cm of water, the leak rate should be less than 100 ml per minute. If the leakage is greater than 1 liter per minute, the machine should not be used until repaired.[21] ACGIH's [22] proposed threshold limit values (TLV's) are 75 ppm for enflurane and 50 ppm for halothane (8 hr time weighted averages). There is no ACGIH proposed TLV for nitrous oxide.

The NIOSH criteria document is somewhat ambiguous in describing the actual exposure portion of the standard. Such terminology as; "... no worker is to be exposed to concentrations greater than ...", and "... TWA concentrations ... during the anesthetic administration period ...", is difficult to interpret. The NIOSH recommendation appears to apply as a TWA over the period of anesthetic administration and not as an eight hour TWA nor a ceiling limit. This vagueness in the NIOSH recommended criteria has caused confusion and variable interpretation in the literature including an eight hour TWA [23-25], a ceiling limit [21,26-31], an anesthetic administration TWA [21,29,32,33], and an unspecified time period TWA [34,35]. The NIOSH Criteria Document has understandably drawn criticism for this reason.[32]

In spite of this confusion, OSHA has cited several hospitals for failing to meet the NIOSH recommendations by invoking the general duty clause of the Occupational Safety and Health Act. In one case, nitrous oxide levels of 124 and 334 ppm and enflurane concentrations of 2.2 to 2.8 ppm were found. OSHA issued a citation for failure to monitor, failure to institute control measures, and for subjecting personnel to the potential hazards associated with anesthetic gases.[32]

Previous studies

To date there have been only a few studies of veterinarian exposure to anesthetic gases. However, in none of the studies did the authors state over what period of time the averages were determined. Concentrations have been reported to ranged from 1.7 to 16.7 ppm for methoxyflurane, 6.0 to 37.2 ppm for halothane, and 6.0 to 270.0 ppm for nitrous oxide. Ruby, et. al. [27], monitored seventy four methoxyflurane surgeries using personal sampling pumps, Tedlar bags, and a Wilks Miran Model 1A portable infrared analyzer. The results for unscavenged operations indicated the average veterinarian exposure to methoxyflurane was 1.9 ppm and that the technician exposure was 1.7 ppm.

At the University of California at Davis veterinary medical school, concentrations of nitrous oxide, methoxyflurane and halothane were found to be 200 ppm, 6.9 ppm, and 14 ppm respectively in the small animal areas.[36] A United States Air Force study [34] conducted in five different veterinary surgical facilities reported nitrous oxide concentrations ranging from 6 to 270 ppm and halothane concentrations ranging from 0.06 to 37.2 ppm. Another author [37] reports finding an average concentration of 2.3 ppm methoxyflurane during a study of 14 private veterinary practices. In this study, nitrous oxide was also measured in four surgical rooms, three which were nonscavenged and one which was scavenged. The average nitrous oxide level in the nonscavenged rooms was 138 ppm verses 14 ppm in the scavenged room.

In a study at the University of Georgia College of Veterinary Medicine [30], 11 locations were monitored using charcoal tubes with GC analysis. One hundred and fifty six halothane ten minute grab samples were collected from these various locations. Sixty five percent of the grab samples were below and 35 % were above the NIOSH recommended criteria of 2 ppm. Thirty six methoxyflurane grab sample results were below 2 ppm.

In 1979, I conducted a limited study (unpublished) of veterinary anesthetic gas exposures to methoxyflurane. A total of 12 surgeries were sampled using a Wilks Miran 1A spectrophotometer. Seven surgeries with nonscavenged, inflated endotracheal tube cuffs were monitored. The veterinarian average exposure was 16.7 ppm with peaks as high as 30.9 ppm. Two nonscavenged surgeries were monitored in which the endotracheal tube cuff were deflated. The average exposure concentration was 18.7 ppm with a peak concentration of 62.4 ppm. Installation of a non-commercial vacuum equipped scavenging system, reduced average exposure of three additional surgeries to 1.9 ppm with peaks of 5.8 ppm. All time weighted averages were determined over the period of anesthetic administration.

Methods and materials

Study population selection

In order to ascertain the hazard faced by veterinarians under good work conditions, an evaluation of anesthetic gas exposures was conducted via a field study of private practice small animal clinics through-out the Salt Lake Valley. Veterinarians were identified via the Wasatch Veterinarian Medical Association membership directory and the use of the telephone yellow pages. The clinics studied were selected based on the data obtained from 36 pre-survey questionnaires. A total of 73 questionnaires were sent out with a response rate of 49 %. By using only individuals that responded to the questionnaire, the potential of a selection bias exists. Recognizing the possible selection bias resulting from this method, ten of the non-respondent veterinarians were contacted by phone. Communication with them did not reveal any factors which indicated exposure or work conditions were different from the cooperative group.

The 36 returned questionnaires were categorized by type of anesthetic agent used and whether the facility was equipped with a scavenging system or not. The two most frequently used anesthetic agents were chosen to be studied and ten facilities were randomly selected. Five facilities (2 scavenged and 3 nonscavenged) were chosen for each anesthetic agent. Thirteen different veterinarians were monitored while performing 38 surgeries (22 surgeries involved the use of methoxyflurane and 16 using halothane). Of the 38 surgeries, five were multiple or back to back nonscavenged surgeries. The multiple surgeries were evaluated to determine the potential for gas build-up in the operating rooms. In order to include the multiple surgery data with the individual surgery data, the previous surgery background concentration was subtracted from each of the following surgeries.

Sampling method

Real time measurements of exposures were obtained using a Wilks Miran model 103 spectrophotometer. Methoxyflurane (2,2-dichloro-1,1-difluoroethyl methyl ether) was analyzed at 12.0 micrometer wavelength and halothane (2-bromo-2-chloro-1,1,1-trifluoroethane) at 12.3 micrometers. The Miran 103 limit of detection is reported to be 0.08 ppm for halothane and 0.07 ppm for methoxyflurane.[38] The spectrophotometer was coupled to a strip chart recorder. Tygon tubing was used as the sampling hose. Preliminary tests using a closed loop system were performed to determine if the anesthetic agents would be adsorbed/absorbed by the tygon. No loss was detected. The Miran was calibrated pre and post sampling using prepared concentrations of the two anesthetic gases to be studied. The electronic calibration was also checked daily before and after each use.

Survey procedures

Veterinarians were asked to refrain from using materials such as fluorocarbon aerosol sprays, formalin, water sprays, and sanitizers or scrubs which contained alcohol in order to minimize interferences with the Miran. With the exception of six surgeries, all animals were initially anesthetized with an injectable anesthetic (Bio-tal, Acepromazine, or Ketamine). The other six animals were induced using nitrous oxide administered in the preparation room. All surgeries were performed using an endotracheal tube with the cuff inflated and a rebreathing (semi-closed) system. Once intubated, anesthesia was maintained by inhalation methods. Breathing zone monitoring of the veterinarians was performed by affixing the tygon sampling hose to their lapels. Spot checks were made at both the pop-off valve and endotracheal tube positions to determine typical off-gasing concentrations. In addition, concentrations throughout the operating room were evaluated to determine the waste gas distribution. A leak test was performed on each piece of anesthesia equipment before actual monitoring began. If the equipment leak rate exceeded one liter per minute, that piece of equipment was not included in the study. By doing so, the poorly maintained machines were eliminated. Consequently, the study conservatively reflects typical rather than worst case exposures.

Results and discussion

The results of the questionnaire indicated that 44 % of the veterinarians used methoxyflurane and 33 % used halothane. Eighty one percent used endotracheal tubes and sixty one percent used recirculating type breathing systems. Veterinarians averaged two hours of surgery per day with each surgery averaging 40 minutes performed at an average oxygen flowrate of 1.5 liters per minute. Fifty eight percent of the anesthesia machines were equipped with some sort of scavenging system. Surprisingly, 25 % of the respondents did not know when the last time their anesthesia equipment was leak tested, and another 28 % indicated that their equipment had never been leak tested. Only 17 % of the machines had been checked within the last 12 months. Of the 20 machines leak tested during the study, only nine (45 %) were found to be in acceptable condition (leak rate less than 100 ml/min) according to NIOSH recommended criteria. Another five had moderate leakage (between 100 and 1000 ml/min) and six were found to have unacceptable leakage (greater than 1000 ml/min). Five of the six unacceptable machines had a leak rate in excess of 5 liters per minute.

During this study, the oxygen flowrate used was not really a function of the size of the animal. Most veterinarians set the flow at a high enough rate to handle the largest animal that they normally operate on, and left it that way for all surgeries. By doing so, an excessive amount of oxygen and anesthetic agent were supplied for small animals. A large portion of this unused gas eventually was dumped out the pop-off valve or released to the room when the animals were disconnected from the anesthesia machine. This practice could significantly increase the overall waste gas concentration within the operating room.

Various forms of scavenging were found in use during this study. The term scavenging means the capture of waste gases at the pop-off valve and venting them to the outside or absorbing them. The most common form of scavenging was the use of charcoal filters for absorbing waste gases. The second most frequent method of scavenging was passive venting of the anesthetic gases through walls or windows to the outside. Only one mechanically assisted system was seen. Although not really a form of scavenging, numerous machines were vented to the floor.

The results of the 38 surgeries monitored are illustrated in Table I. The time weighted averages are calculated over the anesthetic gas administration period. All concentrations are reported as standard temperature and pressure (25 degrees centigrade and 760 mm Hg) equivalents. The data is stratified by anesthetic agent and by scavenging/non-scavenging conditions. Overall, the results indicate that veterinarians can have significant anesthetic waste gas exposures during nonscavenged operations. If all the anesthesia machines inspected had been included in this study, the exposure levels would likely have been much higher. The surgery data was further stratified by animal weight (less than 30 pounds and greater than 30 pounds) and surgery time (less than 30 minutes and greater than 30 minutes). The comparison of this data is provided in Table II. Because the data distribution was lognormal, a Wilcoxon Rank Sum nonparametric test was performed to determine the significance of surgery time, animal size, and system scavenging. The TWA mean for each category of nonscavenged operation was compared to the TWA mean for each category of scavenged operation. Several of the halothane categories (ie., < 30 lbs, < 30 min, and overall) showed statistical significance at the 0.05 level. Seventy percent of the nonscavenged halothane results exceeded the NIOSH criteria but none of the scavenged halothane results were greater than 2 ppm. Scavenging greatly reduced overall halothane exposures. Nineteen percent of the nonscavenged methoxyflurane results exceeded the NIOSH criteria while all of the scavenged methoxyflurane exposure levels were below the NIOSH recommendations. The difference between methoxyflurane scavenged and nonscavenged levels however were not statistical significant at the 0.05 level. Many investigators have reported that scavenging is an effective means of reducing waste anesthetic gas exposures.[3,10,18,21,28,36-40] One author [10] found that scavenging was capable of reducing anesthetic concentrations by 91 % for nonrebreathing systems and 85 % for rebreathing systems. In another study [37], an 81 % reduction in overall levels was achieved by using a scavenging system.

Overall, the halothane concentrations were much higher than the methoxyflurane concentrations. Similar findings were noted in other studies.[27,30,41] This is probably due to the difference in vaporizer designs [30,41]; halothane's higher vapor pressure [41]; and because less anesthetic agent is required to produce equivalent anesthesia with methoxyflurane.[30] Because of halothane's out of circuit vaporizer design, higher oxygen flow rates are required.[30,41]

Spot monitoring around the endotracheal tube revealed less than 0.5 ppm for both halothane and methoxyflurane with the cuff inflated. When the cuff was not inflated, the concentration exceeded 18 ppm for halothane and 26 ppm for methoxyflurane (the upper calibrated limits of the

Miran). Leakage around the endotracheal tube has previously been reported as a source of anesthetic waste gas pollution in the operating room.[42,43] In addition, NIOSH [39] indicates that a 50 % reduction in waste gas concentrations can be obtained by using an endotracheal tube verses a mask. As expected, the concentrations around nonscavenged pop-off valves exceeded the upper calibrated limits of the Miran.

Measurements at different locations in the operating rooms showed that there is rapid dispersion of both anesthetic gases. There was very little, if any difference between the veterinarian's exposure and that of others present in the room. Concentrations at floor level were similar to those in the breathing zone. This parallels others' findings [8,37], and supports the statement that the molecular weight, density [44], and gas buoyancy [8] are negligible in the gas distribution of low concentration gas mixtures. Venting pop-off waste to the floor is an ineffective means of reducing exposures.[8,28]

The trend observed for multiple, back to back surgeries was the same for both halothane and methoxyflurane - a gradual build-up of anesthetic gas in the surgical room even with the use of scavenging. As would be expected, the build-up was faster in nonscavenged rooms than scavenged rooms. Figure 1 shows the trend for three back to back nonscavenged surgeries and three back to back scavenged surgeries for both halothane and methoxyflurane. The surgery time in minutes for each surgery was as follows: methoxyflurane - nonscavenged 34, 29 & 36 (99 total) - scavenged - 24, 21 & 46 (91 total); halothane - nonscavenged 20, 30 & 29 (79 total) - scavenged - 33, 13 & 26 (72 total). Overall, the data suggests that scavenging, although a viable means for reducing waste gas concentrations, is not sufficient to control waste gas exposures. Being a point source control measure, scavenging does not remove waste gases released from other parts of the anesthesia equipment nor gases released due to poor work practices.

In one facility which was equipped with a ceiling exhaust fan, one surgery was monitored without the use of the fan and one surgery with the use of the fan. Both surgeries were performed using the same nonscavenged anesthesia machine. Ventilation measurements revealed 16.7 air changes per hour (ac/hr) in the medium size operating room (25.4 cu meter / 895 cu feet). The TWA over a 12 minute surgery without use of the fan was 3.1 ppm with a peak concentration of 6 ppm. Using the exhaust fan, the TWA concentration was less than 0.08 ppm for a 13 minute surgery. This represents over a 38 fold reduction in the exposure concentration. Dilution air, whether supply or exhaust, can effectively reduce gas concentrations from nonscavenged and poorly maintained anesthesia machines.

Conclusions and recommendations

The results of this study indicate that veterinarians can have significant exposure to anesthetic waste gases during individual surgeries and even more so during back to back surgeries. The major sources of anesthetic gas pollution include poorly maintained anesthesia equipment and excessive oxygen flowrate. In previous studies, careless work practices had been estimated to cause 91 to 95 % of waste gas concentrations in the surgical room.(10) The lack of adequate engineering control systems compounds the problem and allows the build-up of waste gases. The use of a scavenging system can greatly reduce exposures but is limited overall in what it can do. However, by using system scavenging along with dilution air, anesthetic waste gas exposures can easily be maintained below the currently recommended levels.

The best means for controlling anesthetic gas emissions is to promote a viable and effective multi-faceted waste gas management program. This program should consist of four major components: good ork practices; on-going anesthesia machine preventive maintenance; regular waste gas monitoring; and, effective engineering control systems (scavenging and dilution air). Good work practices include the following: starting gas flow only after induction; performing surgeries with the endotracheal tube cuff inflated; occluding the Y-piece if the breathing circuit must be disconnected during surgery; emptying the breathing bag into the scavenging system; flushing the patient with oxygen before disconnecting; and using an oxygen flowrate appropriate for the animal size. Daily low pressure leak testing of the anesthesia equipment should be standard policy with a maximum leak rate of 100 ml/min. Personnel exposure monitoring should be conducted quarterly to determine the effectiveness of the overall waste anesthetic gas program. All operating rooms should be equipped with mechanical ventilation to provide a minimum of fifteen air changes per hour of dilution air.

Industrial hygientists should be aware of the controversy concerning interpreting the NIOSH criteria document and should insure they specify what their anesthetic gas results represent. NIOSH should publish clarification on the intent of the criteria document.

TABLE I

Veterinarian Anesthetic Gas Exposures

METHOXYFLURANE NONSCAVENGED RESULTS

TEST #	WEIGHT	SURGERY TIME	TWA-PPM	PEAK-PPM
1	13	20	< .07	< .07
2	20	42	.19	1.11
3	15.5	17	.46	.60
4	10.5	17	< .07	.56
5	30	35	.19	.77
6	35	88	1.32	1.96
7	30	32	2.89	3.84
8	35	68	2.99	4.35
9	17.9	14	< .07	< .07
10	24	18.5	.63	1.28
11	15.5	29	.43	1.46
12	35	46	1.01	2.99
13	41	44	2.61	4.52
14	19.5	34	1.93	7.42
15	22	29	.46	1.46
16	10	36	< .07	1.79
OVERALL	--	--	.96	--

METHOXYFLURANE SCAVENGED RESULTS

TEST #	WEIGHT	SURGERY TIME	TWA-PPM	PEAK-PPM
1	42	30	< .07	< .07
2	15	24	.36	.77
3	57	21	.21	.43
4	30	46	.87	1.11
5	15	23	.60	1.35
6	9.7	15	< .07	< .07
OVERALL	--	--	.35	--

TABLE I Con't

HALOTHANE NONSCAVENGED RESULTS

TEST #	WEIGHT	SURGERY TIME	TWA-PPM	PEAK-PPM
1	64	23	3.02	8.57
2	22	20	7.23	15.19
3	12	45	9.19	14.72
4	13	85	6.55	11.50
5	20	9	1.30	4.21
6	30	39	3.37	7.34
7	29	48	1.90	5.07
8	30	22	1.71	4.78
9	12	17.7	3.09	6.01
10	31	70	1.15	4.40
OVERALL	--	--	3.85	--

HALOTHANE SCAVENGED RESULTS

TEST #	WEIGHT	SURGERY TIME	TWA-PPM	PEAK-PPM
1	49	33	< .08	< .08
2	20.5	13	.15	.49
3	17	26	< .08	< .08
4	10.5	10	< .08	< .08
5	10.5	41	< .08	< .08
6	37	13	< .08	< .08
OVERALL	--	--	.09	--

TABLE II

Weight and Time Stratified
Anesthetic Waste Gas Results

METHOXYFLURANE

	n	NONSCAVENGED AVG CONC	SE	WILCOXON RANK SUM	n	SCAVENGED AVG CONC	SE
WEIGHT							
<30 #	10	.44	.18	1.000	3	.34	.15
>30 #	6	1.84	.47	0.053	3	.35	.26
TIME							
<30 MIN	7	.31	.09	1.000	4	.29	.12
>30 MIN	9	1.47	.40	0.238	2	.47	.40
OVERALL	16	.96	.27	0.285	6	.35	.13

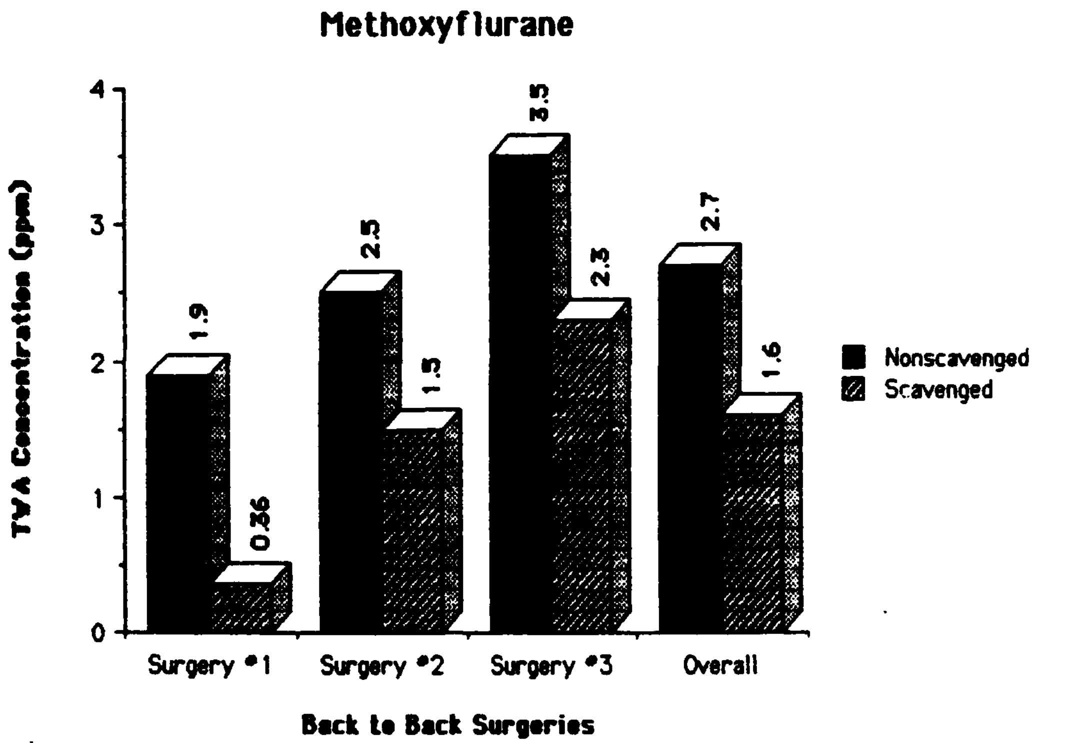
HALOTHANE

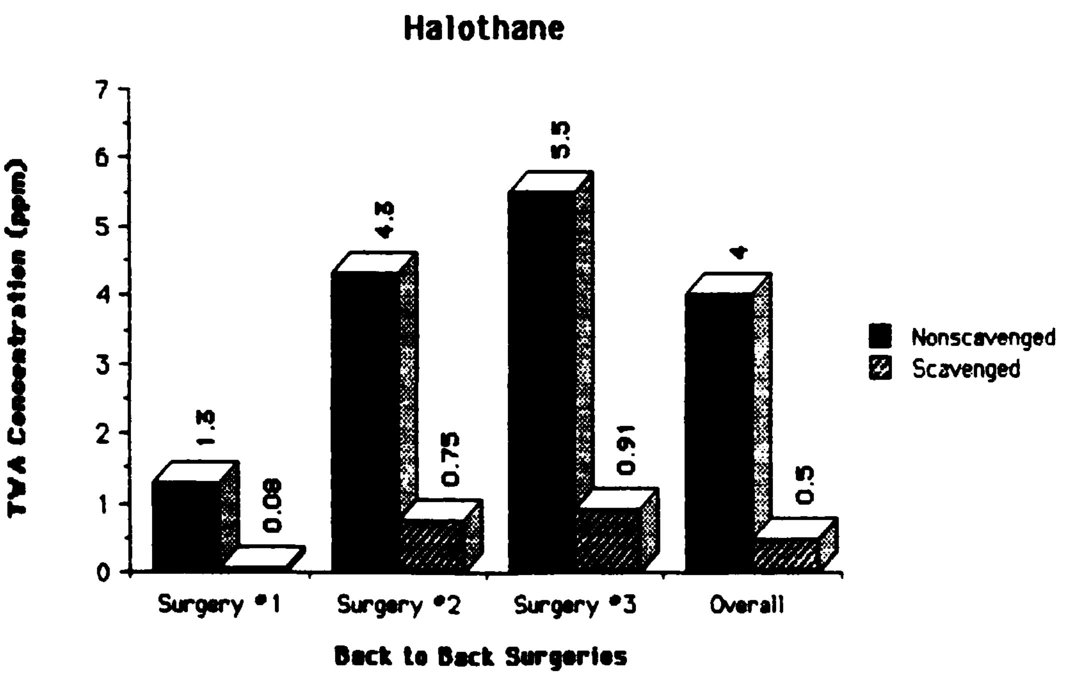
	n	NONSCAVENGED AVG CONC	SE	WILCOXON RANK SUM	n	SCAVENGED AVG CONC	SE
WEIGHT							
<30 #	5	3.27	1.05	0.020	4	.10	.02
>30 #	5	4.43	1.51	0.081	2	.08	.00
TIME							
<30 MIN	6	4.88	1.31	0.014	4	.10	.02
>30 MIN	4	2.31	.53	0.105	2	.08	.00
OVERALL	10	3.85	.89	0.001	6	.09	.01

Avg Concentration - PPM

FIGURE 1

Multiple Surgery Trend





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