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Nitrous Oxide and Occupational Exposure: It's Time to Stop Laughing

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Although nitrous oxide (N_2O) has been widely used since 1844, in recent years it has been implicated in a number of serious health hazards such as reproductive, nerve, liver, and kidney disorders. The National Institute of Safety and Health (NIOSH) recommends a limit of 25 ppm for chronic exposure to N_2O in the dental office. Our study monitored ambient N_2O levels in the dental office. N_2O levels were compared for procedures performed in open clinics and private operatories as well as with and without a gas-scavenging system. Measurements were taken in the Dental Breathing Zone (DBZ) and Dental Chair Foot (DCF) at regular intervals. A four- to eightfold increase in average N_2O levels was noted in the DBZ for unscavenged versus scavenged procedures. A three- to fourfold increase for unscavenged versus scavenged procedures was similarly noted in the DCF. N_2O were significantly higher in private operatories than in open clinics, due to limited room volumes and in the DBZ over the DCF, due to mask leakage and increased oral exhalation. Scavenged N_2O levels for both operatory types did not meet NIOSH guidelines. In contrast to previous studies using any form of gas removal, our study shows a significant decrease in N_2O level achieved with an adequate scavenger system. With only four states regulating the use of N_2O, and with concern over its deleterious effects growing, additional states and the federal government are expected to enact legislation regulating the use of N_2O in the near future.

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Nitrous oxide (N_2O) has been considered one of the safest anesthetics since its use was introduced in 1844. It has become one of the most commonly used anesthetics, yet studies have shown that prolonged exposure to high concentrations of N_2O is associated with adverse effects.

It has been suggested that operating room staff are exposed to an occupational hazard, the pollution of the air in surgical suites with anesthetic gases.[1] This potential hazard is not limited to the operating room, as similar risks have been reported for dentistry.[2] The extent of the risk to dental staffs, however, is still a subject of considerable controversy. Concern over chronic and acute exposure to N_2O has been heightened by animal studies demonstrating fertility problems in male and female rats,[3–5] reductions in litter size and weight,[6] and increased risk of first trimester abortion.[1]

Several epidemiological studies have suggested that serious health effects may result from chronic low-level exposure to inhalation anesthetics. A review of the literature indicates that anesthesiologists, nurse anesthetists, and operating room personnel demonstrate higher rates of irritability, headache, nausea, bearing children with congenital abnormalities, spontaneous abortion, involuntary infertility, lymphoid malignancies, cervical cancer, hepatic and renal disease, neurological disease, and suicide as compared to nonoperating room staff and physicians.[7–9]

There are over 30,000 dental offices in the United States that use N_2O.[10] This would indicate that nearly 120,000 dental personnel are chronically exposed to N_2O, a majority of which are female. Competition for patients among general dentists has made the use of N_2O more popular. The dental office staff are often exposed to greater levels of waste anesthetic gases, particularly N_2O, than operating room personnel.[11,12] Middendorf et al[13] measured ambient concentrations of N_2O within the worker's breathing zone as well as throughout the suites in a number of dental offices. Nitrous oxide levels in all operatories studied were noted to be above the National Institute of Occupational Safety and Health (NIOSH)[14]

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recommended level of 25 ppm. Adjoining waiting room and office areas demonstrated background levels over 25 ppm following N_2O administration. Major sources of N_2O exposure to personnel were noted from leaks around the nasal mask and the patient's orally exhaled air. Scavenger systems were installed in 12 of the 27 offices studied. The 12 offices with scavenger systems had levels greater than 25 ppm, with peak levels in the dentist's and assistant's breathing zone ranging from 132 to 880 ppm. Maximum levels ranged from 152 to 815 ppm in those offices lacking scavenger systems. The scavenging units used in this study did not prove to be effective in reducing operatory N_2O levels.

Even though animal studies are not directly transferable to human studies, they have been utilized as an acceptable model for human studies. A recent study attempted to mimic human exposure conditions and rates through a carefully designed and controlled laboratory rat model. Female rats were exposed to acute high levels (30%) of N_2O (8 hr/day) for 4 days, to encompass one ovulatory cycle. All exposed rats exhibited abnormal ovulatory cycles. Two animals exposed on the morning of the day of ovulation did not have an ovulatory cycle for 2 weeks. Two rats exposed on the day prior to ovulation exhibited abnormal cycles for the duration of the experiment. Control rats exposed to oxygen and compressed air maintained a normal 4-day estrous cycle.[15]

There are at present few specific regulations governing the handling and administration of N_2O by dentists. Boards of Registration in Dentistry in only 20 states have instituted any form of recommendation for the use of N_2O. Even fewer states have demonstrated legislative action to enforce these recommendations. Though four of the 20 states—Massachusetts, Tennessee, Wisconsin, and Utah—require the installation and use of scavenger systems during N_2O administration, no state regulates permissible exposure levels. Most states only require that the dentist attend certified formal instruction in N_2O administration in order to obtain licensure. Recently, some states have also required on-site inspection of offices administering N_2O.

The NIOSH guidelines consider N_2O to be hazardous, in that exposures above 25 ppm during the time of administration may cause adverse health effects. They recommend that gas concentrations in the dental suite be minimized. Employee exposure should not exceed a time-weighted average of 25 ppm for a single procedure. They also recommend the maintenance of adequate ventilation and the use of a scavenger system.

No agency or government body has as yet moved to enforce the NIOSH guidelines adequately. Nor has any organization investigated whether the NIOSH-recommended exposure levels of N_2O are realistically obtainable. Adequate ventilation remains undefined. Most dental offices are simple structures, with ventilation systems recirculating contaminated air or exhausting the air near the other ventilator intakes or areas of public access. No standard has been developed for scavenger systems. Although there are several designs available, the ease of use and effectiveness of scavenger systems has yet to be ascertained.

We report here the results of a study to determine the average N_2O exposure level encountered in the dental clinic at the Tufts University School of Dental Medicine. Two operatory designs and a specially developed scavenger system were utilized. The results will be used to evaluate the efficacy of clinic ventilation and scavenger systems as methods to control N_2O exposure. We hope to determine if present guidelines should be modified or more strictly regulated and enforced.

METHODS

A Miniature Infrared Analyzer (MIRAN) 101 Specific Vapor Analyzer manufactured by The Foxboro Company was used to measure N_2O concentrations in the dental clinic. Infrared energy is absorbed by N_2O at a wavelength of 4.45 μm. Current is passed through a nichrome wire that emits light in the infrared spectrum. This light is passed through an optical filter and directed over a 1.5 m pathlength through the sample chamber by a series of mirrors. Light that is not absorbed by the sample hits an infrared detector. The detector converts the light energy into electrical energy, which, after appropriate signal processing, is displayed on the analyzer meter in parts per million of N_2O.

The instrument was calibrated before and during use in this study. Calibration was performed using specified standard and a closed loop method of analysis. The instrument was certified to demonstrate less than 4% error in measurement. The analyzer was purged with uncontaminated air before being brought into the clinical area under analysis. The system was turned on 30 minutes before use, allowing the electronics to warm up. When the system showed little drift in output gain the analyzer was zeroed by measuring the N_2O concentration of uncontaminated air. Slight variations in measurement may be attributed to change in gain or vibration of internal components.

Measurements were taken in two zones of each operatory. The dental breathing zone (DBZ) was defined as the area anterior to the patient bounded by the dentists and/or dental assistant, a point 12 inches from the patient's mouth. The second area of measurement, the dental chair foot (DCF), was located 6 feet from the patient's mouth near the foot of the dental chair. Measurements were taken in and around the study area before the connection of anesthesia devices. Background levels were assessed

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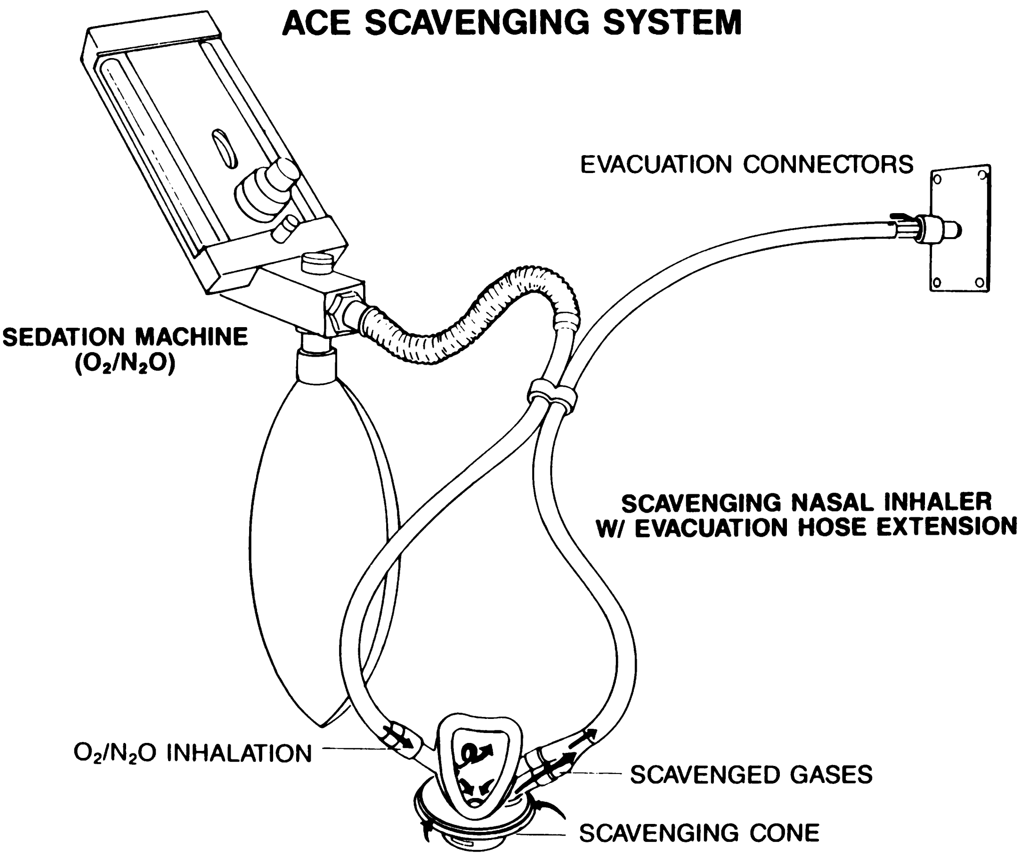


Figure 1. Gas scavenger system.

before connection to clinic N_2O/O_2 source lines. Concentrations of N_2O in the environment were recorded at 0, 5, 10, and 20 minutes, and at successive 10-minute intervals until the gas was terminated. Measurements continued until the area returned to baseline levels.

Nitrous oxide concentrations were determined in both open and closed clinic environments. The open clinic was a large area sectioned into several operatories by 5-foot high partitions. The closed clinic was a private room 9 feet by 9 feet, connected to the clinic by a single door. The door was left open during the procedure to eliminate changes in N_2O resulting from air currents created by the opening and closing of the operatory door.

The dental procedures observed included exodontia and restorations. Each procedure involved the administration of approximately 30% N_2O with O_2 and a local anesthetic. Some procedures used the additional administration of intravenous sedation. Patients were instructed to breathe nasally and to limit verbal response during gas administration.

Nitrous oxide monitoring was also conducted on procedures utilizing a gas scavenger system (Figure 1). The nasal mask was retrofitted for scavenging by replacing the exhaust valve on the face of the mask with a specially designed gas scavenging disc. One side of the mask was connected to the anesthesia delivery system while the opposing side and scavenging disc were connected to the central vacuum line installed in the operatory. This design collects both excess and nasally exhaled gases and removes the vapors from the clinic environment. The scavenger function is controlled by a valve located on the quick-disconnect fitting that attaches the system to the central vacuum line. Nitrous oxide recordings were taken using the same protocol as described for the unscavenged system. In both protocol designs, the mask was placed firmly over the patient's nose so that a good seal is maintained without compromising patient comfort.

RESULTS

A total of 34 procedures were monitored for N_2O contamination in operatories equipped with recirculating ventilation. Sixteen of these procedures were completed without a scavenger system. Six of these unscavenged procedures took place in open clinics, with the balance of ten unscav-

Table 1. Summary Data for Unscavenged Procedures

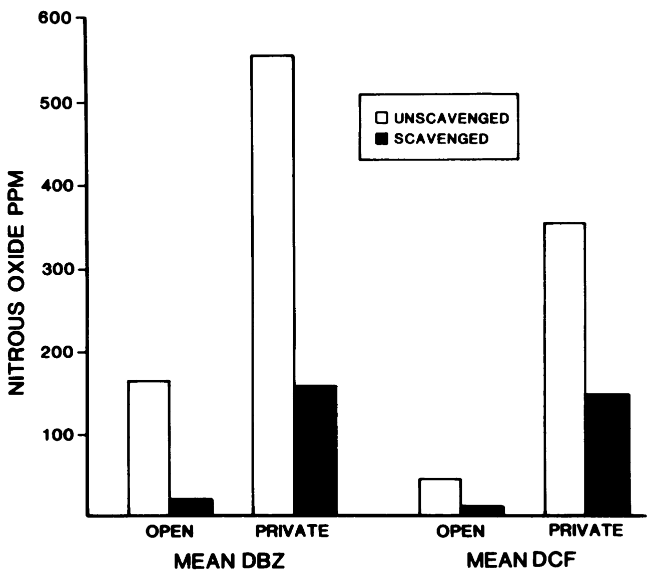
Case	Clinic: open/private	Duration (min)	Mean N_2O Level in DBZ (ppm)	Maximum N_2O Level in DBZ (ppm)	Mean N_2O Level at DCF (ppm)	Maximum N_2O Level at DCF (ppm)	Number of Samples Taken
1	open	70	285	1060	49	100	9
2	open	22	206	1200	31	50	5
3	open	20	80	380	25	40	4
4	open	120	69	2000+	52	60	14
5	open	75	136	2000+	58	70	10
6	open	55	231	900	60	120	8
7	private	50	429	1170	324	450	7
8	private	33	515	1490	425	650	6
9	private	41	714	2000+	241	325	7
10	private	73	277	400	285	360	10
11	private	33	430	800	322	490	6
12	private	23	364	600	319	480	5
13	private	34	397	750	375	500	6
14	private	92	582	1400	557	750	12
15	private	21	472	650	472	650	5
16	private	56	1350+	2000+	538	700	8

DBZ = Dental Breathing Zone; DCF = Dental Chair Foot

enged procedures completed in private operatories. The mean levels of N_2O measured within the DBZ and at the DCF for each procedure are shown in Table 1. The maximum N_2O level measured in each of these areas, number of samples taken, and duration of N_2O administration are also indicated.

The duration of procedures conducted in the open clinic ranged from 20 to 120 minutes, while private operatory procedures ranged from 21 to 92 minutes. Mean levels of N_2O in the DBZ ranged from 69 to 285 ppm in open clinics and 227 to 1350 ppm in the private operatories.

Figure 2. Mean DBZ and DCF in open clinics and private operatories.



Corresponding N_2O levels in the DCF ranged from 25 to 60 ppm in the open clinics and 241 to 557 ppm in the private operatories.

Eighteen procedures were monitored for N_2O contamination in operatories equipped with the scavenger system described earlier. Eight of these scavenged procedures were conducted in the open clinics, with the balance of ten scavenged procedures completed in private operatories. Recorded data for scavenged procedures are indicated in Table 2.

The duration of N_2O administration for those procedures conducted in the open clinic ranged from 27 to 60 minutes. Private operatory procedures ranged from 7 to 85 minutes. Mean levels of N_2O in the DBZ of scavenged open clinics ranged from 4 to 45 ppm and in scavenged private operatories from 102 to 239 ppm. Corresponding levels in the DCF ranged from zero (0) to 33 ppm in scavenged open clinics and 98 to 213 ppm in scavenged private operatories. Overall group means are seen in Figure 2.

Nitrous oxide levels in all operatories were found to dissipate to levels below the analyzer threshold within 10 to 20 minutes after termination of N_2O administration. With this dissipation rate and the time necessary to complete the procedures and reset the operatory for the next patient, all procedures were begun at a zero (0) baseline level for N_2O.

DISCUSSION

The administration of N_2O in the dental office remains a popular procedure, both for pain control and as a marketing tool. Even though it is easy to deliver and is considered

Table 2. Summary Data for Scavenged Procedures

Case	Clinic: open/private	Duration (min)	Mean N_2O Level in DBZ (ppm)	Maximum N_2O Level in DBZ (ppm)	Mean N_2O Level at DCF (ppm)	Maximum N_2O Level at DCF (ppm)	Number of Samples Taken
1	open	52	14	100	6	10	8
2	open	30	40	700	27	50	5
3	open	38	3	50	0	0	6
4	open	55	8	15	1	5	8
5	open	45	10	30	1	10	7
6	open	40	10	15	4	10	6
7	open	60	44	70	22	30	8
8	open	27	45	70	33	55	5
9	private	85	129	200	127	210	11
10	private	19	122	175	121	175	4
11	private	17	183	300	195	300	4
12	private	17	195	900	213	320	4
13	private	41	239	1000	133	180	7
14	private	7	177	280	170	260	3
15	private	10	157	400	142	260	3
16	private	55	174	240	153	200	8
17	private	10	120	220	98	180	3
18	private	67	102	160	102	160	9

DBZ = Dental Breathing Zone; DCF = Dental Chair Foot

safe for short-term administration to patients, with such widespread and common use the hazards associated with long-term exposures to N_2O are not often fully considered. Previous studies have demonstrated that N_2O can be considered a hazardous material. Adverse effects have been shown to result from both high-concentration acute exposures and low-level chronic exposure to the gas. As awareness of the hazards increase, the need for control of N_2O exposure in the denal clinic will become more apparent.

The NIOSH criteria[14] state that the adverse affects associated with chronic exposure to N_2O of prime concern involve decrements in performance, cognition, audiovisual ability, and in dexterity during exposures to the gas. These effects were observed at exposure levels of 500 ppm. Audiovisual decrements were observed in volunteers exposed to levels as low as 50 ppm N_2O has been shown to have the potential to impair the functional capacities of exposed workers. None of these effects were noted at a 25 ppm exposure level. Therefore, NIOSH recommends that the permissible level of exposure to N_2O should be a time-weighted average concentration of 25 ppm during the period of administration.[16]

Variations in health patterns of personnel chronically exposed to trace anesthetic vapors in the workplace have been demonstrated by retrospective epidemiological studies. Data from these types of studies are often confounded by possible incorrect recollections, responder or interviewer bias, and inaccurate data analysis. Although these studies are often questioned, the ADA Ad Hoc Committee on Trace Anesthetics as a Potential Health Hazard in Dentistry has recommended that all dentists using N_2O should employ monitoring and scavenging as part of their routine.

NIOSH recommends that ambient N_2O levels not exceed 25 ppm in the dental operatory as a time-weighted average. Even though the scavenger system significantly decreases N_2O levels in the operatory, these lower levels, in most cases, remained well above the NIOSH guideline. Clinic levels approached recommended levels only when procedures took place in open clinics with cooperative, relaxed patients having good nasal mask fits.

The hazards of N_2O are starting to draw more attention than in the past. As concerns grow, the professional and lay communities will need to respond to these issues. Four of 20 states are including scavenger reqirements in their regulations, and more states are expected soon to follow their example. Many states are now considering or enforcing more strict controls and regulations.

Based on our own data and that of previous investigations, the authors recommend that dental practices using N_2O should install and use an adequate scavenger system, which should be periodically monitored to ensure its effectiveness. Those dental professionals using private operatories should be aware of high N_2O levels in the DBZ and possible introduce a secondary exhaust system (i.e., fan). Those dentists practicing in states not presently requiring a scavenger system should consider installing a system for protecting themselves and their staff, as well as in anticipation of possible legislation requiring the use of scavenger systems and enforced exposure limits.

The intent of this study was not to judge the merits of the use of N_2O. Our purpose was to consider the use of

N_2O in the dental operatory, the NIOSH-recommended limits on exposure, and the administration requirements of various state and local regulating agencies. We questioned the adequacy of a 25 ppm exposure level as an achievable standard and set out to determine whether a new scavenger system design was capable of reducing clinical exposure levels of N_2O to within the required standards. The authors make no comment on the subjects of continued usage or elimination of N_2O from the dental operatory. We recommend that professionals administering the gas make themselves fully aware of both the risks and benefits of N_2O as an anesthetic agent.

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