SCIENTIFIC ARTICLES

Occupational Exposure to Nitrous Oxide in Dental Operatories

Paul J. Middendorf, M.S., David E. Jacobs, B.S., Kenneth A. Smith, M.P.H., David M. Mastro, D.D.S., M.S.
Georgia Institute of Technology, Georgia Tech Research Institute, Environmental, Health, and Safety Division, Atlanta, Georgia

Summary

Occupational exposures to nitrous oxide (N_2O) were measured in numerous dental operatories. In all cases, the National Institute of Occupational Safety and Health (NIOSH) recommended time-weighted average (for one operation) of 25 ppm was exceeded by wide margins (NIOSH considers 50 ppm to be attainable in dental operatories). However, a new risk assessment is necessary to determine appropriate exposure limits. Many of the operatories were not equipped with scavenging systems and none of them used a scavenging device in combination with a local exhaust ventilation system. Scavenging devices and local exhaust ventilation should be used to control nitrous oxide exposures. Leaks in N_2O delivery systems, which were found to be commonplace, should also be controlled. Research and development efforts are needed to improve upon the already existing scavenging devices, and provision for local exhaust ventilation needs to be included in the design of dental operatories.

Introduction

Use of nitrous oxide (N_2O) as an anesthetic agent began in 1844 when a dentist performed a painless tooth extraction after administering N_2O to his patient.[1] Since then, nitrous oxide alone or in combination with other agents, such as oxygen, halothane (Fluothane), or enflurane (Ethrane), has become the most widely used general inhalation anesthetic throughout the world.[2] It is estimated that approximately 100,000 dental personnel (including 30,000 dentists) are involved in administering N_2O to about 4.5 million patients annually in the United States.[2,3] Other occupationally exposed groups include anesthesiologists, other physicians (e.g., surgeons), anesthetists, operating room nurses, and veterinarians.

Nitrous oxide is preferred over the ethers because it is nonflammable. Until recently, it was believed that N_2O was not metabolized and was nontoxic.[4] For this reason, it was thought to be superior to chloroform, whose deleterious effects on operating room personnel were first recognized in the late 1880s.[5] N_2O, a colorless inorganic gas, has a somewhat sweet and pleasant odor. During and after a typical dental procedure, a patient absorbs approximately 30 liters of N_2O which is rapidly eliminated from the body through the lungs and air passages.

An increasing body of data has suggested that serious health effects result from chronic exposures to trace amounts of residual anesthetic agents. Jastak and Greenfield[6] reviewed the results of previous accounts indicating that anesthesiologists have suffered higher rates of irritability, headache, nausea, spontaneous abortion, premature delivery, children with congenital abnormalities, lymphoid malignancies, cancer in females, hepatic and renal disease, and even suicide. Most of these findings were obtained from hospital personnel who have been exposed to multiple anesthetic agents. However, other workers who are exposed almost exclusively to nitrous oxide suffer some of the same effects.[3]

Dental personnel are exposed to concentrations of N_2O two to three times greater than are operating room employees, and are more likely to use the gas without mixing it with halogenated anesthetics (only 19% of dentists recently surveyed in 1980 indicated they used the latter in their practices).[7] In short, epidemiological data from dental workers will help to reveal the adverse health effects specific to N_2O without the confounding factors found in surveys of hospital workers. Only one such survey has been completed to date.[7]

Accepted for publication February 21, 1986.

Address correspondence to: Paul J. Middendorf, Georgia Institute of Technology, GTRI/EHSD, Atlanta, Georgia 30332.

A survey of 30,000 dental personnel completed in 1980 indicated rates of spontaneous abortion were significantly higher for wives of male dentists and for female dental assistants. Furthermore, women directly exposed to N_2O without other anesthetic agents showed a doubling in the rate of spontaneous abortion compared to women who were not exposed. Other results include statistically significant increases in congenital abormalities among newborns of female assistants directly exposed to N_2O, together with increased rates of liver, kidney, and neurological disease in both males and females. Reports of numbness, weakness and other nonspecific neurological symptoms were found to occur four times more often among heavily exposed dentists than among unexposed dentists.[7]

Of course, such surveys have many potential sources of error. A recent review of epidemiological surveys[8] of exposures to all anesthetic gases outlines some of the uncertainties. The greatest of these probably lies with the method of data collection. Specifically, do members of the unexposed control group tend to underreport adverse reproductive outcomes more than the exposed group?

Clearly, studies of the biochemical mechanisms and animal toxicity testing must be completed to reach a firm conclusion about the health hazards of occupational exposures to nitrous oxide. Some studies have been completed which give an indication of the mechanisms involved in nitrous oxide toxicity. An incompletely reversible polyneuropathy similar to that of pernicious anemia has been attributed to the ability of N_2O to inactivate certain enzymes by oxidizing the cobalt in vitamin B_{12}. This can lead to a decrease in serum methionine, which reduces the conversion of uridine to thymidine, one of the four nucleosides of deoxyribonucleic acid (DNA). The overall effect is a decrease in DNA production resulting in the inhibition of cell division. Tissues with a high rate of cell turnover would be most susceptible, possibly explaining the reproductive and carcinogenic problems found by Cohen.[9]

One of the major problems in assessing the risk of the dental worker is that the majority of animal toxicological studies use short exposure times and high levels of exposure (with the intent of simulating patient exposure), and small numbers of animals. Nitrous oxide has been shown to adversely affect the hematologic system, the cell-mediated immune system, and the nervous system. Depression of bone marrow activity has occurred at levels as low as 1000 ppm. Production, motility, chemotactic response (the ability of white blood cells to reach sites of infection), and the tumor-killing ability of lymphocytes have all been shown to be depressed by nitrous oxide.[10] Cases of chronic abusive self-administration of nitrous oxide have also been reported, resulting in serious myelopathy or neuropathy with evidence of addictive and suicidal tendencies.[11]

The adverse reproductive effects of nitrous oxide are receiving the greatest attention of late. Rats have shown evidence of reversible testicular damage after being exposed intermittently to 20% N_2O for 28 days. These rats also exhibited abnormal giant multinucleated sperm cells and decreased sperm counts.[12] It has been suggested that since vitamin B_{12} plays an important role in male fertility, N_2O may adversely affect sperm metabolism and motility by a mechanism similar to that involved in DNA production described earlier; i.e., oxidation of vitamin B_{12}. Male rats exposed to N_2O concentrations of 5000 ppm produced a significantly smaller litter size when mated with unexposed females than a control group. The offspring also showed postnatal growth depression.[13]

Intermittent exposures of gravid rats to as low as 0.1% N_2O have caused significant reduction in litter size, and at 1%, the postnatal growth rate of rats exposed during the prenatal period was reduced.[14]

Finally, Bruce and Bach[15] worked with human volunteers and found significant decrements in visual perception, immediate memory, and a combination of perception, cognition, and motor responses at 50 ppm N_2O. These effects were not found at concentrations of 25 ppm.

Based on these and other findings, The National Institute of Occupational Safety & Health (NIOSH) had recommended that "occupational exposure to nitrous oxide, when used as the sole anesthetic agent, shall be controlled so that no worker is exposed at time weighted average (TWA) concentrations greater than 25 ppm during anesthetic administration."[3]

However, the NIOSH recommendation was based in large part on the psychomotor effects found by Bruce and Bach. Subsequent research[16-18] failed to find such effects at the same level of exposure. Another NIOSH-sponsored study states that concentrations as low as 50 ppm can be attained when the recommended control measures are implemented.[19]

Given these discrepant findings, a new risk assessment of the effects of nitrous oxide exposure should be performed to determine an acceptable exposure level. Until that time, the recommendations of the ad hoc committees of the American Dental Association and the American Society of Anesthesiologists should be implemented. These recommendations call for the application of control measures *to maintain the lowest reasonably achievable concentrations in the operatory* whenever inhalation anesthetic agents are administered[20] (our emphasis). The following data indicate that control methods have not been implemented by a significant percentage of practicing dentists; even when in place, the measures have been inadequate.

Methods and Materials

Nitrous oxide concentrations were measured using a MIRAN (Miniature Infra Red Analyzer) 1A-CVF Gas

Analyzer manufactured by The Foxboro Company (Model 063-0015). Nitrous oxide absorbs strongly at a wavelength of 4.45 μm. A major source of interference in this region is carbon dioxide, which absorbs infrared light at 4.43 μm. To reduce the potential for significantly false positive readings, an analytical wavelength of 4.50 was chosen. In addition, care was taken to minimize introduction of directly exhaled air (which would be high in CO_2) when measuring concentrations in a worker's breathing zone. However, tests with exhaled breath indicate no measurable increase in absorbance at the chosen wavelength. A pathlength of 7.20 meters, a slit width of 1 mm, and a meter response time of 1 second were used.

Calibration was performed by injecting known amounts of N_2O into a closed loop calibration system (The Foxboro Company, Model No. 106) with a known volume.

The instrument was calibrated before and after monitoring was performed. An original computer program determined the concentrations of N_2O in the closed loop calibration system, and then calculated the concentrations from the absorbances measured in the various dental operatories by averaging the data obtained from the pre- and postcalibrations and linearly interpolating between the calibration points. Table 1 provides calibration data for Dentist VI.

Before entering the dental suite, the instrument was purged with clean, uncontaminated air and zeroed outside the dentist office. Such rezeroing was usually unnecessary. Care was taken not to change the various parameters (wavelength, pathlength, slit width, etc.) while the survey was in progress, and also until postcalibration had been performed. Sources of error include slight movement in these settings, variation in instrument gain, jarring of internal mirrors and wavelength filter, and placement of the particulate filter through which the air to be measured was drawn.

When possible, measurements were taken at various locations throughout the suites, offices, waiting rooms, and operatories before the N_2O had been turned on for the day. Once the procedure was underway, measurements of general room levels and of the dentist's or dental assistant's breathing zone were taken. Measurements were generally made at 3–5 min intervals. Data were usually generated until well after the procedure had been completed to help interpret the effectiveness of the room ventilation. The probe was also placed in the immediate vicinity of potential leak sources including: tank valves, high and low pressure connections, "Y" connector and vacuum lines for scavenging equipment, point of scavenging line exhaust, explosion relief valves, and ventilation bags (used to ventilate the patient in the event of respiratory arrest) to help identify items in need of maintenance.

TABLE 1. Nitrous Oxide Calibration Points MIRAN IA-CVF Gas Analyzer

ML N_2O Added	N_2O (ppm)	Precalibration Absorbance	Postcalibration Absorbance
0	0.00	0.000	0.000
.5	8.78	0.048	0.045
1	17.55	0.087	0.086
1.5	26.33	0.120	0.120
2	35.11	0.155	0.151
3	52.66	0.215	0.215
4	70.21	0.269	0.265
5	87.76	0.310	0.311
6	105.32	0.355	0.355
8	140.42	0.430	0.430
10	175.53	0.500	0.501
12	210.63	0.561	0.560
14	245.74	0.617	0.611
16	280.84	0.665	0.671
18	315.95	0.711	0.709
20	351.05	0.755	0.750
22	386.16	0.795	0.805
24	421.26	0.830	0.820
26	456.37	0.860	0.851
28	491.48	0.891	0.880
30	526.58	0.920	0.910
32	561.69	0.950	0.930
34	596.79	0.975	0.960
36	631.90	1.010	0.980
38	667.00	1.050	1.000

Results

Air Concentrations

The ambient concentrations of nitrous oxide were determined within workers' breathing zones as well as throughout the suites of a number of dental offices. The results presented in Table 2 indicate that levels in all operatories were well above the NIOSH recommended level of 25 ppm. The adjoining waiting rooms and offices displayed background levels above 25 ppm after the N_2O was administered. A great deal of variation existed among the dental operatories in frequency of use of N_2O, the depth of anesthesia required (i.e., flow rate and the concentration of gas used), the suite ventilation system, and effectiveness of different scavenging systems.

The major sources of nitrous oxide exposure to dental personnel were identified as leaks around the nasal mask and exhaled air from the patient's mouth. Sharp increases in ambient concentrations were observed when anesthesia was first administered, and also when the gas was turned off. This was probably caused by higher rates of mouth breathing (talking, laughing, etc.) and uncontrolled releases from the nose mask, which in some cases was not yet attached to the patient. Increases could also be observed during the procedure when the patient talked, or when the patient's mouth was opened for surgery. Scavenging equipment was in use in only 12 of the 27 offices surveyed.

TABLE 2. Operatory Nitrous Oxide Concentrations[a] (ppm)

Dentist	Before N_2O administered	During N_2O administration mean[d]	Duration of procedure(s) (minutes)	Number of measurements included	Maximum at dentist's breathing zone	Waiting room levels	Number of leaks found[b]	Scavenging system used?
I	18-33	68	60	19	132	17-28	4	Yes
II	11	106	27	14	171	52-147	0	No
III	ND	81	98	22	475	—	2	No
IV	14	128	30	29	152	34	0	No
V	ND	102	—	18	361	45	4	Yes
VI	19	497	90	33	667	131	7	No[c]
VII	6	501	77	36	632	533	6	Yes
VIII	5	597	82	30	667	81	4	Yes
IX	3	110	46	9	296	18	2	Yes
X	4	184	55	10	372	21-36	1	Yes
XI	ND	603	70	12	735	355	3	No
XII	26	434	120	25	734	170	0	No
XIII	ND	64	69	13	151	121	0	Yes[e]
XIV	15	323	10	4	584	27	2	No
XV	91	498	50	20	734	140	4	No
XVI	ND	223	52	17	534	114	1	No
XVII	ND	409	40	15	734	133	1	No
XVIII	19	414	19	6	659	55	4	No
XIX	88	244	48	13	463	62	1	No
XX	ND	659	86	10	659	122	1	Yes
XXI	ND	421	120	14	815	49	1	No
XXII	10	417	94	29	797	46	1	Yes
XXIII	ND	496	62	13	667	134	0	No
XXIV	ND	320	41	20	667	10	0	Yes
XXV	ND	444	110	30	880	61	6	Yes
XXVI	4	184	70	10	647	63	0	Yes
XXVII	1	617	20	7	660	251	1	No

[a] Includes measurements taken at dentist's or dental assistant's breathing zone and at selected locations in operatory.
[b] Significant leaks other than those from around the patient's mask.
[c] Passive scavenging system.
[d] Not time-weighted average.
[e] Low flow rate used.
ND=None detected.

Control Methods

A wide variety of scavenging systems was observed in the course of the surveys. A passive scavenging system, in which no vacuum was connected to the exhaust line, was found to be ineffective (see Dentist VI). Another system consisting of a vacuum exhaust port located on the exterior of one side of the mask was also ineffective (see Dentist VIII). The presence of a scavenging device did not necessarily lead to lower concentrations in the operatory (see Table 2). Flow rate, concentration administered to the patient, frequency of use, room dimensions of the operatory, and dilution ventilation rate all need to be considered in comparing one facility to another.

The typical dentist office is located in an office building or medical complex. Since the ventilation systems are designed as heating and cooling systems, they are not intended to remove air contaminants. Figure 1 graphically shows the concentrations of nitrous oxide at various times throughout a day for one procedure in Dentist III's operatory. The system had been completely turned off for three months. At 9:00 a.m. the system was turned on, and by 10:00 a.m. the background levels had risen from nondetectable up to 2 ppm due to leaks in the gas delivery system. At approximately 10:00 a.m., N_2O was first administered to the patient. Levels of N_2O rose quickly during the 90-min procedure, up to 209 ppm. When the system was turned off, the levels began to decrease because of ventilation and diffusion out of the area. The effective exhaust rate was calculated at 0.79 air changes per hour. This may be somewhat lower than the actual exhaust rate because exhalation of N_2O by the patient and resuspension of the gas which had been adsorbed onto surfaces in the work area contributed to ambient N_2O levels. In short, it is important to prevent entry of N_2O into the general work area where it is very difficult to control exposures, especially in modern office buildings where air

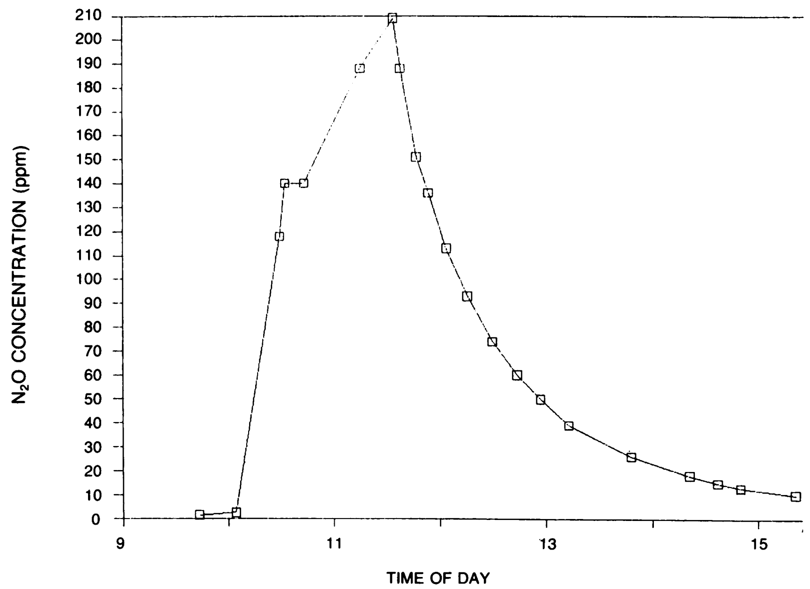

Fig. 1 — Nitrous oxide levels from one administration

exchange rates are likely to be quite low. In comparison, hospital operating rooms typically have 15-17 air changes per hour.

Discussion

Other investigators have found short periods of regular exposure to levels as high as 7000 ppm.[21-23] Peak exposures of 24,000 ppm have been reported in operatories not equipped with scavenging devices.[24]

A scavenging system reduces the amount of waste gas coming from leaks around the nasal mask. The reduction is accomplished through use of vacuum lines which exhaust from a double mask system providing for entry of the gas and exhaust of exhaled gases to a location outside the operating theater (usually a drain). Several workers have investigated the relative efficiencies of commercially available scavenging systems with wide variation in the control of nitrous oxide.[25-27] Scavenging devices in dentistry (as opposed to general surgery) are limited in effectiveness because nose masks (instead of full face masks) are used and the open mouth of the patient allows entry of N_2O into the operatory.

Local exhaust ventilation systems, consisting of a vent opening near the patient's mouth, and a duct leading to a fan which exhausts to the outside, have also been recommended as a control measure, but none were found in any of the dental operatories surveyed. NIOSH and others[27] have recommended the use of local exhaust systems, together with scavenging systems to reduce exposures to N_2O to acceptable levels. Our data show that even the better scavenging systems alone have not succeeded in reducing concentrations to the recommended levels; further field studies are needed to confirm this observation.

One study of local exhaust systems found that an optimal capacity of about 200 m^3/hr and a position 20 cm or less in front of the patient satisfactorily reduced occupational exposures to N_2O.[27] Placement of the exhaust port as close as possible to the patient's mouth and determination of sufficient air flow to achieve efficient capture of N_2O while the patient exhales are critical factors that should be considered in the design of such a system. Such devices are necessary to control significant entry of N_2O into the operatory caused by talking or laughter of patients, uncooperative patients, and only partially effective scavenging systems. Some dentists have reported that office building managers do not want to install exhaust ventilation systems or alter existing ventilation systems. Control measures can be more easily and cheaply installed if they are included in the design of the new or refurbished operatory.

Rubber dams may also limit mouth breathing, and together with a good scavenging system, could significantly reduce ambient levels. Placement of a saliva evacuation device inside the patient's mouth can also help evacuate nitrous oxide that would otherwise enter the work area. However, the exhaust should be to the outside of the building to prevent contamination of workspace air. Additional control measures and sources of exposure are described below.

1. Training and education of personnel in proper administration and operation equipment is essential.
2. The data in Table 2 suggest that significant leaks tend to be commonplace in dental operatories. A

regular air monitoring program should be implemented to monitor performance of scavenging systems and also to check for leaks. Gas-tight connections in scavenging and gas delivery systems should be substituted for the slip-on hose type fittings commonly used.

3. Scavenging and anesthetic equipment should be effective without regard to the heating/air-conditioning system in use.
4. Gases should be exhausted from the building away from heating, ventilation, and air-conditioning fresh air intake vents.
5. N_2O should be administered only to those patients truly in need of such treatment. Routine or unnecessary use of N_2O should be avoided.
6. Elective administration of N_2O to pregnant patients should be avoided. This is most important during the first trimester; however, it may be difficult to eliminate exposures during this period since pregnancy may go undetected for part of this time.
7. Patients using N_2O should be informed of the potential adverse health effects to dental operatory personnel, and the role the patient can play in minimizing dental personnel exposures. Patients may choose not to use N_2O, or if they do, they may use smaller quantities, breathe evenly through the nose, and limit talking.

Conclusions

A full understanding of the toxic effects and mechanism(s) associated with nitrous oxide (especially on the reproductive system) is still some time away. However, enough evidence currently exists to warrant concern about occupational exposure in dental operatories. The 25 ppm level recommended by NIOSH was based on data suggesting that memory capabilities, motor and visual skills would not be impaired at this concentration. The recommendation did not take into account other health hazards associated with chronic exposures to low levels of N_2O. Therefore, a re-evaluation of the NIOSH recommendation is necessary because of the new toxicological information on nitrous oxide. A risk assessment needs to be completed as part of this effort. Further educational activity is also needed to underscore the importance of minimizing occupational exposures to nitrous oxide. The potential risks of nitrous oxide exposures to dental operatory personnel must be balanced against two factors: the need to control anxiety in patients; and the potential risk to patients when other methods of pain and anxiety control are used. Since the use of nitrous oxide is likely to continue, effective control technology should be developed.

Currently available control technology should be implemented, and new ideas for the control of N_2O must be developed, such as improved scavengers and local exhaust ventilation.

Scavenging systems alone are not likely to reduce ambient concentrations of nitrous oxide in the dental operatory and the adjoining office spaces to the NIOSH recommended time-weighted average for one operation of 25 ppm. Field studies of the effectiveness of additional control measures need to be performed.

Acknowledgments

The authors wish to express their gratitude to Dean Lail of Georgia Tech for his typing and editorial services.

The dental operatory surveys described in this manuscript were conducted as a part of a contract with the U.S. Department of Labor/OSHA under the On-Site Consultation Program.

References

1. Woodware LT: *The History of Surgery,* Monarch Books, Inc., Derby, CT, 1963 pp. 58-66.
2. Jones TW and Greenfield W: Trace anesthetics as a potential hazard in dentistry. JADA 95:751-756, 1977.
3. NIOSH Criteria for a Recommended Standard, Occupational Exposure to Waste Anesthetic Gases and Vapors. Publication No. DHEW 77-140, 1977.
4. Greene, NM: Anesthesia. In *Principles of Surgery,* Schwartz SI, Shires TG, Spencer FC, Storer EH (Eds.), McGraw-Hill, New York, 1974, pp. 445-446.
5. Hewett FW: *Anesthetics and Their Administration,* Macmillan, London, 1907, p.34.
6. Jastak JT and Greenfield W: Trace contamination of anesthetic gases—a brief review. JADA 95:758-762, 1977.
7. Cohen, EN, Brown BW, Wu ML, Whitcher CE, Brodsky JB, Gift HC, Greenfield W, Jones TW, Driscoll EJ: Occupational disease in dentistry and chronic exposure to trace anesthetic gases. JADA 101:21-31, 1980.
8. Tannenbaum TN and Goldberg RJ: Exposure to anesthetic gases and reproductive outcome. J Occupa 659-668, 1985.
9. Baden JM, Rice SA, Serra M, Mazze R: Thymidine and methionine syntheses in pregnant rats exposed to nitrous oxide. Anesth Analg 62:738-741,
10. Brodsky J: Nitrous oxide toxicity—is occupational exposure to nitrous oxide a health hazard? Workshop at Stanford University Medical Center, March 21, 1983.
11. Lunsford JL, Wynn M, Kwan W: Nitrous oxide induced myeloneuropathy. J Foot Surg 22:222-225, 1983.
12. Kripke BJ, Kelman AD, Shah NK, Balogh K, and Handler AH: Testicular reaction to prolonged exposure to nitrous oxide. Anesthesiology 44:104, 1976.
13. Vieira E, Cleaton-Jones PE, and Mayes D: Effects of intermittant 0.5% nitrous oxide/air (v/v) on the fertility of male rats and the post-natal growth of their offspring. Anesthesia 3:319-323, 1983.
14. Vieira E, Cleaton-Jones PE, Austin J, Fatti PL: Intermittent exposure of gravid rats to 1% nitrous oxide and the effect on the postnatal growth of their offspring. SA Med 21:106-108, 1978.
15. Bruce DC and Bach MJ: Trace effects of anesthetic gases on behavioral performance of operating room personnel. HEW Publication No. (NIOSH) 76-169,1976.
16. Gambill AF, McCallum R, Henrichs T: Psychomotor performance following exposure to trace concentrations of anesthetics. Anesth Anal 58:475-482, 1979.
17. Smith G, Shirley AW: Failure to demonstrate effect of trace concentrations of nitrous oxide and halothane on psychomotor performances. Br J Anesthesia 49:65-70, 1977.

18. Venables H, Cherry N, Waldron H, Buck L, Edling C, Wilson H: Effects of trace levels of nitrous oxide on psychomotor performance. Scand J Work Environ Health 9:391-396, 1983.
19. Whitcher LE, Zimmerman DC, Pizali RL: Control of Occupational Exposure to N_2O In the Dental Operatory. DHEW (NIOSH) Publication No. 77-171, 1977.
20. Jones TS, Allen GD, Brown BW, Greenfield W, Griffiths R, Getter L, Hayden J, Kerr IL, Snead MP, Sweptson BA, Whichter CE, Lemke G: Report of the ADA Ad Hoc Committee on trace anesthetics as a potential health hazard in dentistry. ADA News 8:3, 1977.
21. Millard RI, Corbett TH: Nitrous oxide concentrations in the dental operatory. J Oral Surg, 32:593-594, 1974.
22. Scheidt MJ, Stanford HG, Ayer WA: Measurement of waste gas contamination during nitrous oxide sedation in a non-ventilated dental operatory. Anesth Progr 24:38-42, 1977.
23. Campbell RL, Hennifan MA, Reist PC, Gregg JM: Exposure to anesthetic waste gas in oral surgery. J Oral Surg 35:625-630, 1977.
24. Hennifan MA, Reist PC, Campbell RL: Anesthetic waste gas exposure in dental surgery. Industrial Hygiene Assoc J 39:69-73, 1978.
25. Hallonsten AL: Nitrous oxide scavenging in dental surgery I. a comparison of the efficiency of different scavenging devices. Swedish Dent J 6(5):203-13, 1982.
26. Hallonsten AL and Lofstrom JB: Physical properties of nitrous oxide-oxygen sedation equipment used in dentistry. Swedish Dent J 6(4):133-148, 1982.
27. Hallonsten AL: Nitrous oxide scavenging in dental surgery II. An evaluation of a local exhaust system. Swedish Dent J 6(5):215-223, 1982.
28. Carlsson P, Hallen B, Hallonsten AL, Ljunggrist B: Thermocamera studies of nitrous oxide dispersion in dental surgery. Scand J Dent Res 91:224-230, 1983.

CONTINUING EDUCATION CALENDAR

First Announcement:

5th International Dental Congress On Modern Pain Control

Sydney, Australia
May 11-13, 1988

For further information contact:

5th International Dental Congress on Modern Pain Control
Conventions Department
P.O. Box 489, G.P.O.
Sydney, N.S.W. 2001
Australia