

Ambient nitrous oxide levels during pediatric sedations

Robert J. Henry, DDS, MS Roy G. Jerrell, DDS

Abstract

Various studies have implicated generalized health problems with chronic exposure to trace levels of nitrous oxide. Recent investigations have reported that higher-than-recommended levels of nitrous oxide exist in the breathing zone of the dental staff. This study was undertaken to accurately determine waste nitrous oxide levels during pediatric sedations and to evaluate the effect of scavenging in reducing environmental exposure. Conscious sedations were performed on 20 uncooperative 2–4-year old children. Each child was assigned randomly to one of two groups, a scavenged group and a non-scavenged control. Sedations were accomplished with oral administration of chloral hydrate and hydroxyzine. All patients received nitrous oxide (40%) in oxygen throughout the procedure. Waste nitrous oxide levels were monitored 22–24 in from the dentist's nose using an infrared spectrophotometer and recorded by a microprocessor. Results indicate that environmental levels of nitrous oxide exceed the National Institute for Occupational Safety and Health (NIOSH) recommendations by 12 times, regardless of whether a scavenging system was employed or not. It is concluded that the scavenging system tested in this investigation may not be as efficient as previously thought at complying with NIOSH recommendations.

Introduction

Nitrous oxide is a commonly used drug in pediatric dentistry which possesses analgesic, anxiolytic, and psychosedative properties. Its use is considered safe for the patient, but is of concern as an environmental hazard for dental personnel chronically exposed to ambient nitrous oxide.

Epidemiologic and laboratory animal studies have associated the following health risks with chronic exposure to waste levels of nitrous oxide:

1. Increased spontaneous abortion rates of dental staff and unexposed wives of dentists
2. Infertility and reproductive difficulties
3. Congenital anomalies and fetal growth retardation
4. Increased incidence of cervical cancer
5. Kidney and liver disease
6. Adverse effects on bone marrow function and the immune response
7. Generalized neurological disorders (Jastak and Greenfield 1977; Cohen et al. 1980; Mathieu et al. 1980; Brodsky et al. 1981; Gutmann and Johnsen 1981; Vieira et al. 1983; Eger 1985).

A transient cause and effect relationship has been demonstrated in laboratory animals (Kugel et al. 1989). Additional evidence suggests that health problems in humans may persist long after exposure to waste nitrous oxide has ceased (Cohen et al. 1980; Tannenbaum and Goldberg 1985).

The exact concentration of waste nitrous oxide that is harmful to humans has yet to be determined. Several clinical investigations have reported that waste levels exceed National Institute for Occupational Safety and Health (NIOSH) recommended limits, 25 ppm time-weighted average exposure (Badger and Robertson 1982; Christensen et al. 1985; Jacobs and Middendorf 1986; Middendorf et al 1986; Ship 1987). In addition, these authors question the effectiveness of current scavenging devices at complying with NIOSH recommendations. The accurate quantification of ambient levels of nitrous oxide is difficult. It is clear that some level of environmental exposure does exist. The negative health consequences of such exposure remain unestablished.

Pediatric dentists commonly utilize nitrous oxide in their practices and are at a potentially greater environmental health risk than other dental professionals. Quantification of ambient nitrous oxide levels is the first step in a series of investigations exploring this hypothesis. Pediatric sedations commonly are performed in small, isolated "quiet" rooms, with nitrous oxide used as an integral part of the procedure. Dental personnel may be at greater health risk, from an environmental standpoint, in this setting. Therefore, this seems to be an

appropriate area for initial investigation. The purpose of this study was to determine the level of waste nitrous oxide existing during chloral hydrate/hydroxyzine sedation of young children and to evaluate the effectiveness of one scavenging device at reducing this exposure.

Materials and Methods

Participants in this investigation were 20 healthy (ASA I) children ranging in age from 24 to 45 months old, with a mean age of 35 months. All patients selected were determined to be candidates for sedation based on generally accepted criteria. Institutional Review Board approval and parental informed consent were obtained prior to patient participation in this investigation.

All sedations were performed in an isolated operatory measuring 10 x 10 x 8 ft. The room air exchange rate was determined to be 120 cf/min, equivalent to 9.0 room air changes per hr. Sedations were performed according to guidelines established by the American Academy of Pediatric Dentistry (American Academy of Pediatric Dentistry 1985). All patients received chloral hydrate (Noctec: Squibb Co., Princeton, NJ) at a dosage of 75 mg/kg, plus 25 mg of orally administered hydroxyzine (Vistaril: Pfizer, New York, NY). Patient treatment was accomplished using a body and head restraint (Papoose Board: Olympic Medical Group, Seattle, WA), precordial stethoscope, and pulse oximeter (Nellcor N100: Nellcor Inc., Hayward, CA). All dental procedures were conducted routinely with the aid of an assistant and use of local anesthesia, rubber dam, and high-speed evacuation.

Children were assigned randomly to two groups of 10 subjects. Group 1 patients received nitrous oxide from a standard portable nitrous oxide anesthesia unit (MXR: Porter Instrument Co., Hatfield, PA) equipped with a Porter/Brown scavenging mask assembly (Porter/Brown: Porter Instrument Co., Hatfield, PA) connected to the local evacuation system. The proper evacuation rate for scavenged gas was established by adjusting the floating metal ball on the scavenging unit. Group 2 patients received nitrous oxide via the same unit and mask, but no attempt was made to remove waste nitrous oxide.

An infrared spectrophotometer (Miran 1B: Foxboro, South Norwalk, CT) was used to detect ambient levels of waste nitrous oxide. The spectrophotometer measured infrared absorbance of nitrous oxide at 4.5 μ m and was set to detect nitrous oxide concentrations in a range from 0–2000 ppm. Precalibration of the Miran 1B was performed by the manufacturer. Baseline zeroing of the instrument with clean air was done prior to each use.

Each patient received nitrous oxide with oxygen throughout the procedure. New rubber goods were installed on the nitrous oxide unit for this investigation,

and no leaks were detected when tested in a manner similar to that recommended by Whitcher and coworkers (1977). Each child received 40% nitrous oxide in oxygen at a flow of 4–5 liters per min. Total gas flow was adjusted depending upon the degree of distention of the reservoir bag. After completion of dental treatment, 100% oxygen was administered for five min.

Ambient nitrous oxide concentrations were monitored 22–24 in from the dentist's nose at a location above the patient's chest. Data from the spectrophotometer was input to a microprocessor (DL332F Datalogger®: Foxboro, South Norwalk, CT). Waste nitrous oxide levels were recorded beginning with the introduction of nitrous oxide and terminated at administration of 100% oxygen at the end of each appointment. The Datalogger® collected data from the spectrophotometer at one-sec increments and was programmed to store one min intervals of data continuously throughout each appointment. Data recorded with the Datalogger was transferred to microcomputer for storage and statistical analysis.

Statistical Analysis of Data

The Datalogger provided the minimum value, time weighted average (TWA), and maximum value of nitrous oxide for each one-min interval during the procedure. The mean TWA and the mean maximum concentration of waste nitrous oxide was computed for each group and compared to NIOSH recommendations. An unpaired *t*-test was used to determine the efficiency of scavenging at reducing the concentration of waste nitrous oxide; the significance level was established at $P < 0.05$.

Results

The ambient nitrous oxide levels in the dentist's and dental assistant's breathing zone are listed in Table 1. The mean age of participants for each group was not statistically different. The mean TWA concentration of waste nitrous oxide during all 20 sedation procedures was 338 ppm. The range of ambient nitrous oxide detected was 0–583 ppm. Group 1 patients, in which

TABLE 1. Ambient Nitrous Oxide Levels.

	Mean Appt. Length	Mean TWA ppm \pm SEM	Mean Max. ppm \pm SEM
Scavenged N = 10	65.1 min	300.8 \pm 18.5*†	459.9 \pm 36.5*†
Nonscavenged N = 10	66.5 min	375.2 \pm 15.7†	539.4 \pm 36.5†

* Significantly different from nonscavenged control group at $P < 0.01$ (*t*-test).

† Significantly different from NIOSH recommend limit (25 ppm Time Weighted Average) at $P < 0.0001$ (*t*-test).

scavenging was utilized, averaged significantly lower nitrous oxide levels compared to Group 2 subjects, in which scavenging was not employed. This difference was statistically significant at the $P < 0.01$ level. Both groups, however, displayed waste nitrous oxide levels significantly greater than the 25 ppm limit recommended by NIOSH ($P < 0.0001$). In this study the NIOSH limit was exceeded 96% of the time, regardless of whether scavenging was employed.

Figure 1 demonstrates the concentration of nitrous oxide over time for both groups. Ambient nitrous oxide levels exceeded NIOSH standards within the first five min of the procedure. The scavenging effect, during the five- to 10-min interval, became significant at maintaining a lower ambient nitrous oxide level. The scavenging device utilized in this investigation produced approximately a 25% reduction in waste nitrous oxide levels after the tenth minute. The scavenging system's efficiency diminished with increased duration of nitrous oxide administration. A nonsignificant difference between groups was observed 55 min into the procedure.

Discussion

The analgesic, anxiolytic, and psychosedative properties of nitrous oxide are useful in pediatric dentistry. The popularity of its use is evident from a recent survey that indicated more than 87% of Diplomates utilize nitrous oxide for selected patients (Davis 1988). Although nitrous oxide is beneficial and likely safe for patients, various negative health effects exist for dental personnel chronically exposed to trace amounts of this agent.

The exposure time and concentration of waste nitrous oxide that is harmful to humans has yet to be established. Guidelines recommended by NIOSH state that nitrous oxide levels should be controlled so that no worker is exposed to a time weighted average (TWA) concentration of nitrous oxide greater than 25 ppm (NIOSH 1977). The American Dental Association also has advised that control measures be taken to maintain the lowest concentration of nitrous oxide possible. The results of this investigation demonstrate that ambient nitrous oxide levels during chloral hydrate/hydroxyzine sedation exceeded NIOSH recommendations. The ramifications of this may be significant. On May 23, 1988 the Occupational Safety and Health Administration (OSHA), a part of the Department of Labor, mandated that employees have a right to know potential hazards of the substances with which they work (ADA 1988). From our results, it seems that compliance with NIOSH recommendations according to the OSHA mandate may be quite difficult and thus present an employee health concern.

Historically, the concern regarding a possible environmental health risk from waste anesthetic gas expo-

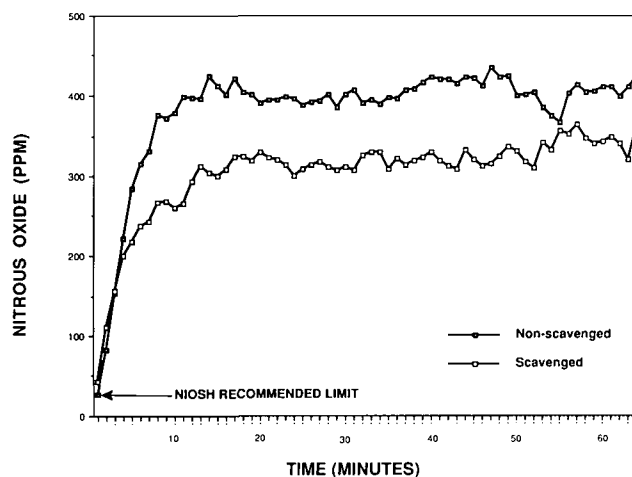


Fig 1. Group mean nitrous oxide levels for scavenged and non-scavenged patients depicted over time. The scavenging effect, as well as the group's approximation to NIOSH's 25 ppm recommended limit are illustrated.

sure dates back to a study of Russian anesthesiologists (Vaisman 1967). More recently, Cohen and coworkers (1980) described results from a health survey of 61,197 dentists and chairside assistants. Their report found that personnel in dental offices that utilized nitrous oxide eight hr per week or more had a significantly greater incidence of liver, kidney, and neurological disease, and that assistants and wives of male dentists both experienced an increase in spontaneous abortion rates (Cohen et al. 1980). Subsequent to these findings, scavenging systems were developed which were felt to be effective at reducing waste nitrous oxide to safe levels (Whitcher et al. 1977; Vean and King 1979; Hallonsten 1980; Tonn and Whitcher 1980; Hallonsten 1982). Recently, however, several investigations have shown that ambient levels of nitrous oxide exceed NIOSH recommendations to various degrees (Badger and Robertson 1982; Almquist and Young 1983; Christensen et al. 1985; Middendorf et al. 1986; Ship 1987). Disparity among these reports makes it difficult to determine whether the presence of an environmental hazard exists. The disparity in quantifying waste nitrous oxide levels is due to several factors, including variation in the populations studied, the instrumentation utilized, and the research design. Therefore, interpretation of previous work and its clinical application is difficult. The present study was undertaken to: 1) accurately quantify ambient nitrous oxide levels in the dentist's breathing zone, and 2) to determine the influence of one commonly used scavenging device at decreasing this exposure.

This investigation improved on previously published reports. First, more sophisticated equipment was utilized which allowed detection of nitrous oxide at a wider range (0-2000 ppm). No readings off the instru-

ment's scale were encountered. Second, the Datalogger provided increased accuracy in the recording of results. This programmable microprocessor recorded all nitrous oxide levels detected by the spectrophotometer at one-sec increments and integrated directly with a microcomputer. Thus, continuous accurate recording of data throughout each procedure was accomplished. Third, ambient nitrous oxide levels were studied during performance of actual dental treatment and on an age group of patients similar to those of a typical pediatric dental practice. Information was obtained in a way that would have broader clinical application than earlier studies. Finally, previous studies continued monitoring air samples long after nitrous oxide administration ceased, making the TWA exposure reported substantially low. The TWA exposure has yet to be investigated while nitrous oxide is being utilized in lengthy procedures.

Three factors should be considered when evaluating the results of this investigation. First, the spectrophotometer probe distance for monitoring waste nitrous oxide was 22–24 in from the dentist's nose, which is greater than the 6–10 in distance used in previous investigations (Whitcher et al. 1977; Tonn and Whitcher 1980; Christensen et al. 1985). This distance was chosen to minimize effects of carbon dioxide and water vapor in the area of the sampling probe. Infrared absorbance of these two elements appear similar to nitrous oxide, and this is a potential source of error in nitrous oxide detection by the spectrophotometer. Surgical masks also were worn to further reduce the possibility of respiratory interference near the probe area. In this way, the minimum ambient nitrous oxide levels were accurately recorded during this investigation. The actual nitrous oxide levels closer to the dentist's and assistant's nose may in fact have been higher. This was observed in our pilot study where up to 1861 ppm of nitrous oxide was found 10 inches from the dentist's nose.

Second, the study group of young children received chloral hydrate and hydroxyzine. It is possible that these patients somehow may respond differently than nonsedated subjects receiving routine treatment in the open clinic setting. These results are, however, an accurate prediction of ambient nitrous oxide levels that can be expected during performance of sedations. It is also the authors' view that similar nitrous oxide levels would be found if nitrous oxide were used on nonsedated patients in a similar treatment room.

Third, it has been suggested that an enclosed operatory may influence the ambient nitrous oxide levels. The room air exchange rate was determined and found to be relatively high. Reports have found that nitrous oxide levels in an open clinic setting seem to be lower than in a closed operatory (Christensen et al. 1985; Jacobs and Middendorf 1986). From this observation, one would

expect to observe lower ambient nitrous oxide levels if the same procedures were performed in an open clinic setting.

The toxic effects from environmental exposure to waste levels of nitrous oxide are not fully known. The results of this study demonstrated that higher waste nitrous oxide levels exist in the breathing zone of the dentist and chairside assistant than were previously thought. Scavenging was not successful at reducing this exposure to NIOSH recommendations. The practical implication of these results relates to employee health and possible government regulation.

This study found that the dental staff is exposed, at times, to ambient nitrous oxide levels 12 times higher than NIOSH recommendations, regardless of whether scavenging is utilized. This investigation corroborates other studies that show higher-than-recommended levels of nitrous oxide existing in the dental operatory (Badger and Robertson 1982; Christensen et al. 1985; Middendorf et al. 1986; Ship 1987).

Although OSHA currently does not single out nitrous oxide, there is substantial information which has linked increased rates of spontaneous abortion and miscarriage, as well as other generalized health problems, with chronic exposure to low levels of nitrous oxide (Tannenbaum and Goldberg 1985). There is a very real concern that the dentist may one day be found negligent with regard to nitrous oxide practices under the OSHA mandate. The prudent practitioner would be wise to employ control measures to limit release of waste gas, examine their nitrous oxide delivery system for leaks, have ambient levels tested, and inform employees, especially pregnant females, of these possible but as yet unproven health concerns.

Conclusions

Nitrous oxide levels which exceeded NIOSH recommendations existed during chloral hydrate/hydroxyzine sedations performed in a closed operatory. The scavenging system tested significantly reduced the concentration of waste nitrous oxide but did not approach the NIOSH recommended limit. The 25 ppm recommendation established by NIOSH requires reevaluation, since it does not seem a realistic or attainable waste nitrous oxide level for typical dental offices. Health consequences of such exposures remain unanswered.

Further study is required in order to determine a safe and attainable environmental level of nitrous oxide. Technique modification and/or equipment improvements are needed to limit nitrous oxide exposure and ensure optimal health.

Dr. Henry and Dr. Jerrell are associate professors, Department of Pediatric Dentistry, College of Dentistry, University of Florida,

- Gainesville, FL. Reprint requests should be sent to: Dr. Robert J. Henry, Dept. of Pediatric Dentistry, University of Florida College of Dentistry, Box J-426, J. Hillis Miller Health Center, Gainesville, FL 32610.
- Almquist TC, Young JM: Clinical evaluation of nitrous oxide/oxygen conscious sedation delivery systems. *J Dent Res* 62:173, 1983.
- American Academy of Pediatric Dentistry: Guidelines for elective use of conscious sedation, deep sedation, and general anesthesia in pediatric patients. *Pediatr Dent* 7:334-37, 1985.
- American Dental Association: Hazards Communication Program, Reprinted from ADA News, April 25 and September 19, 1988, Chicago, IL, 1988.
- Badger GR, Robertson CW: Nitrous oxide waste gas in the pedodontic operator. *J Am Dent Assoc* 104:480-81, 1982.
- Brodsky JB, Cohen EN, Brown BW, Wu ML, Whitcher CE: Exposure to nitrous oxide and neurologic disease among dental professionals. *Anesth Analg* 60:297-301, 1981.
- Christensen JR, Vann WF, Linville DR: Measurement of scavenged nitrous oxide in the dental operator. *Pediatr Dent* 7:192-97, 1985.
- 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. *J Am Dent Assoc* 101:21-31, 1980.
- Davis MJ: Conscious sedation practices in pediatric dentistry: a survey of members of the American Board of Pediatric Dentistry College of Diplomates. *Pediatr Dent* 10:328-29, 1988.
- Eger EI II: Nitrous oxide/N₂O. Eger EI II, ed. New York: Elsevier, 1985. pp 259-79.
- Gutmann L, Johnsen D: Nitrous oxide induced myeloneuropathy: report of cases. *J Am Dent Assoc* 103:239-41, 1981.
- Hallonsten A: The use of nitrous oxide analgesia in Sweden: clinical testing of nitrous oxide scavenging systems. *Analgesia* 3:17-21, 1980.
- Hallonsten A: Nitrous oxide scavenging in dental surgery: a comparison of the efficiency of different scavenging devices. *Swed Dent J* 6:203-13, 1982.
- Jacobs DE, Middendorf PJ: Control of nitrous oxide exposures in dental operatories using local exhaust ventilation: a pilot study. *Anesth Prog* 33:235-42, 1986.
- Jastak JT, Greenfield W: Trace contamination of anesthetic gases—a brief review. *J Am Dent Assoc* 95:758-62, 1977.
- Kugel G, Letelier C, Atallah M, Zive M: Chronic low level nitrous oxide exposure and infertility. *J Dent Res* 68:313, 1989.
- Mathieu A, Mathieu D, Kerman R: T-lymphocyte function and PMN chemotaxis in anesthesiologists and other O.R. personnel. *Anesthesiology* 50:29, 1980.
- Middendorf PJ, Jacobs DE, Smith KA, Mastro DM: Occupational exposure to nitrous oxide in dental operatories. *Anesth Prog* 33:91-97, 1986.
- National Institute of Occupational Safety and Health: Criteria for a recommended standard, occupational exposure to waste anesthetic gases and vapors. Publ No. DHEW 77-140, 1977.
- Ship JA: A survey of nitrous oxide levels in dental offices. *Arch Environ Health* 42:310-14, 1987.
- Tannenbaum TN, Goldberg RJ: Exposure to anesthetic gases and reproductive outcome. *J Occup Med* 27:659-68, 1985.
- Tonn EM, Whitcher CE: Scavenging of waste nitrous oxide in pediatric dental offices. *J Int Assoc Dent Child* 11:41-46, 1980.
- Vaisman AL: Working conditions in surgery and their effect on the health of anesthesiologists. *Eksp Khir Anesteziol* 3:44-49, 1967.
- Vean AH, King KJ: Measuring N₂O levels in the dental operator. *ASDC J Dent Child* 46:22-27, 1979.
- Vieira E, Cleaton-Jones PE, Mayes D: Effects of intermittent 0.5% nitrous oxide/air on the fertility of male rats and the post-natal growth of their offspring. *Anaesthesia* 38:319-23, 1983.
- Whitcher CE, Zimmerman DC, Tonn EM, Piziali RL: Control of occupational exposure to nitrous oxide in the dental operator. *J Am Dent Assoc* 95:763-76, 1977.

Drug makers held liable

Five tetracycline manufacturers were held liable for failure to warn that the drug causes permanent staining of teeth, reported *American Medical News*.

Four siblings in a Louisiana family who had taken various tetracycline medications between 1957 and 1961 sued the five manufacturers and three detailers, citing failure to warn of the staining that discolored their teeth.

A trial court found that the manufacturers should have known in 1956 that tooth discoloration could be caused by ingestion of tetracycline by pregnant women and by children during the years of tooth formation.

The detailers also were found liable in the original trial. The appellate court affirmed the liability of the manufacturers, but held that the detailers were not personally liable.