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Control of anesthetic gases in dental operatories[1]

by James D McGlothlin, PhD, Paul A Jensen, PE, Thomas J Fischbach, MS, Robert T Hughes, MS, James H Jones, CIH[2]

Mixtures of nitrous oxide (N_2O) and oxygen have been used in dentistry as a general anesthetic agent, an analgesic, and as a sedative for more than 100 years. Today more than 424 000 workers provide dental care (ie, dentists, dental assistants, and dental hygienists) in the United States (1). It is estimated that more than 50% of these workers are potentially exposed to N_2O (2). The adverse health effects of exposure to low levels of N_2O have been demonstrated in epidemiologic and laboratory studies. These health effects include irritability, headache, nausea, congenital abnormalities, spontaneous abortion, infertility, lymphoid malignancies, cervical cancer, hepatic and renal disease, neurological disease, and behavioral performance decrements (3, 4). On the basis of these studies, the National Institute for Occupational Safety and Health (NIOSH) recommended in 1977 that exposures be limited to a time-weighted average (TWA) concentration of 25 ppm during the period of administration (5). Recent laboratory and epidemiologic research has shown impaired synthesis of deoxyribonucleic acid (6), disruption of ovulation (7), and reduced fertility among female dental assistants (Roland et al, unpublished results).

In 1977, NIOSH published a technical report which contained recommendations to control waste N_2O to 50 ppm during administration on the basis of the technical feasibility of existing controls (8). Since then, several NIOSH reports have shown that N_2O has not been consistently controlled to 50 ppm, nor to the NIOSH recommended exposure limit of 25 ppm during administration, when anesthetic gas control scavenging systems were used (9). Because of these deficiencies, NIOSH researchers began conducting field studies of dental operatories that use scavenging systems to provide information about consistently controlling N_2O to the NIOSH recommended exposure limit.

Methods

The following five scavenging systems were evaluated by NIOSH researchers: Fraser-Harlake, Porter-Brown, MDT McKessen, Blue, and Comfort Cushion. The Fraser-Harlake and Porter-Brown scavenging masks were quantitatively evaluated during two in-depth field surveys. The Blue Mask, Comfort Cushion, and MDT McKessen were not evaluated because the design, function, and use of these masks was not sufficiently different from the Fraser-Harlake or Porter-Brown scavenging masks. Two sites were selected for in-depth evaluations of the Fraser-Harlake and Porter-Brown N_2O scavenging systems, a pediatric dental facility and an oral surgical clinic, respectively. During both surveys, air samples were taken in the breathing zone of the dentists or oral surgeons and their assistants. General area samples were also taken, but their results are not reported in this paper because the N_2O concentrations were low (ie, <25 ppm) for most of the samples taken. Personal breathing zone exposures to N_2O were collected in 30-l bags and analyzed with a calibrated Miran 1A infrared gas analyzer according to NIOSH method 6600 (10).

Real-time N_2O sampling was conducted during each dental operation and recorded with the Miran 1A infrared gas analyzer. The sampling port of the analyzer was located near the breathing zone of the dentists and their assistants. The N_2O data were recorded from the analyzer either directly into a portable computer (pediatric dental facility survey) or into a portable data logger (Rustrak Ranger®) and downloaded into a portable computer (oral surgical clinic survey) for analysis.

Portable videotape recorders and camera ensembles were used for both surveys to record work activities. Motion and time measurement techniques were used to document the activities of the dentist and the dental assistant during the operation. In addition, during both surveys, N_2O was monitored with an AGA Thermovision® 782 infrared scanner and image display unit. This image was transmitted to a monitor and videocassette recorder (VCR) for later analysis. Figure 1 shows the basic configuration of the infrared thermography components used to detect and visualize N_2O in dental operatories.

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[1] Disclaimer: Mention of commercial names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

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Results

Pediatric dental facility. In the survey at the pediatric dental facility, the N_2O concentrations exceeded the NIOSH recommended exposure limit in 100% of the operations monitored by NIOSH researchers for both the dentists and their assistants (table 1). The mean N_2O concentration was 438 (SD 359) ppm for the dentists and 141 (SD 134) ppm for the dental assistants. Paired Student t-tests comparing the N_2O personal sample results of the dentists with those of the dental assistants showed a significant difference ($P<0.03$). The differences were attributed to the closer working proximity of the dentist's breathing zone to the patient's mouth compared with the assistant's. When the averaged real-time sampling results [426 (SD 156) ppm] were compared with the averaged results (438 ppm) from the dentist's personal breathing zone, there was no significant difference between the means ($P<0.68$). However, there was a significant difference between the real-time sampling results and the N_2O concentrations among the dental assistants (141 ppm) ($P<0.014$). The difference was due to the closer placement of the sampling probe to the dentist.

The infrared scanning camera helped the NIOSH researchers determine that the Fraser-Harlake mask did not fit the patient's face properly and that there was N_2O leakage between the mask and face seal.

The flow rate of the scavenging system was evaluated with a Dwyer® flow meter. The flow meter

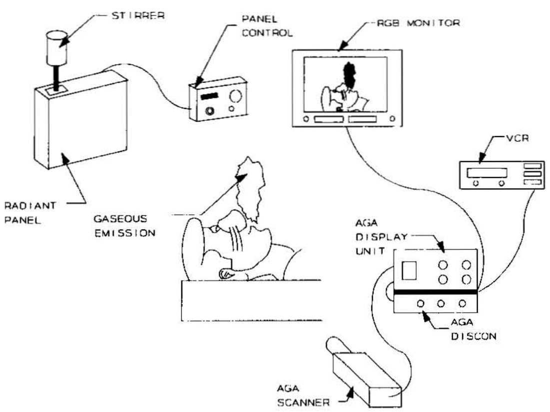

Figure 1. Schematic of an infrared thermography unit to detect nitrous oxide.

Table 1. Summary of personal and real-time sampling data for nitrous oxide (N_2O).

In-depth survey site	N_2O concentration[a] (ppm)								
	Dentist/surgeon			Dental assistant			Real time[b]		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Pediatric dental facility	7	438	359	7	141	134	10	426	156
Oral surgical clinic	7	101	117	7	27	31	9	89	66

[a] Data cells with N<10 resulted from sampling times too short to collect data, or no personal sampling data were collected.
[b] Real-time probe located near the breathing zone of the dentist/surgeon.

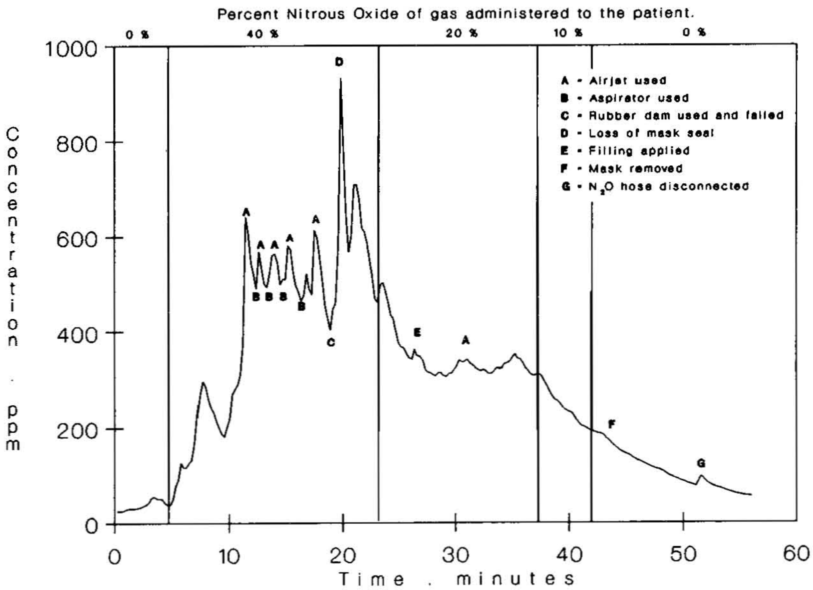

Figure 2. Real-time changes in the nitrous oxide (N_2O) concentration during dental surgery.

showed the exhaust flow rate to be approximately 7 to 12 $l \cdot min^{-1}$ for the operations at the pediatric dental facility. An exhaust flow rate of 45 $l \cdot min^{-1}$ is recommended.

We observed and documented the work practices and changes in N_2O concentration to determine if such activities influenced changes in exposure levels. Changes in exposure levels were attributed to work activities, such as the use of the aspirator, air and water syringes, and drilling of teeth (figure 2). However, these changes in N_2O concentration during the work practices were small and transient compared with the change when the dentist turned the N_2O gas on, when the dentist adjusted the N_2O concentration over the course of the operation, and when the dentist turned the N_2O gas off at the end of the operation.

Oral surgical clinic. The second survey at the oral surgical clinic showed that the N_2O levels exceeded the NIOSH recommended exposure limit in 50% of the operations monitored for oral surgeons [101 (SD 117) ppm] and for 29% of those monitored for their surgical assistants [27 (SD 31) ppm] (table 1). As in the first survey, the difference between the oral surgeons and their assistants was due to the closer working proximity of the surgeons than their assistants. The average real-time N_2O concentrations for these operations were similar [89 (SD 66) ppm] to the exposures of the oral surgeons.

Discussion and concluding remarks

While it is tempting to compare the performances of the Fraser-Harlake and Porter-Brown scavenging systems, it is important to note that the study populations (pediatric versus adult) and the survey sites (pediatric dental facility versus oral surgical clinic) were different for each system. However, enough information was collected to help improve the performance of these systems and reduce the N_2O levels. During the survey at the pediatric dental facility, it was determined that scavenging exhaust rates could be increased from approximately 12 $l \cdot min^{-1}$ to 45 $l \cdot min^{-1}$ to improve significantly the capture efficiency for N_2O. However, when the exhaust rates were increased, noise levels also increased from more air rushing through the mask. As a result the dental assistants would not fully open the scavenging system exhaust valve. In addition, the Fraser-Harlake scavenging system was not equipped with a flow meter to provide information on exhaust rate settings. NIOSH researchers suggested that the noise levels could be reduced if the mask was redesigned by changing the composition of the dome from plastic to rubber and by enlarging the one-fourth inch (0.64 cm) opening of the dome.

The dentists and the oral surgeons worked 8—15 inches (20—38 cm) from the patient's breathing zone, compared with 15—30 inches (38—76 cm) for the assistants. The closer working distance of the dentists and the oral surgeons resulted in significantly higher N_2O exposures. In both surveys, good work practices resulted in lower N_2O exposures. However, the most predictive work practices for determining N_2O levels and their changes were when the dentist or oral surgeon turned the N_2O on, when they adjusted the N_2O level during surgery, and when it was turned off. No other work activity caused as much change. The infrared scanner proved to be a valuable tool in determining N_2O leakage from the scavenging mask, as well as from patient mouth breathing. During both surveys, the NIOSH researchers were able to synchronize the changes in N_2O levels from the real-time data with the videotapes of infrared scanning of N_2O to observe mask leakage and patient mouth breathing. These results indicate that control of N_2O to 25 ppm during administration can be obtained with a well-maintained anesthesia delivery and scavenging system, a scavenging system exhaust rate of 45 $l \cdot min^{-1}$, a scavenging mask with good patient fit, prudent use by dental personnel, and good work practices.

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