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NITROUS OXIDE IN THE DENTAL ENVIRONMENT: ASSESSING THE RISK, REDUCING THE EXPOSURE

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Abstract

This article identifies the potential sources of nitrous oxide in the dental environment and reviews the harmful effects of chronic exposure to nitrous oxide. The author suggests methods of controlling nitrous oxide concentrations to approximate the recommended levels in the dental care environment.

The administration of nitrous oxide mixed with oxygen is a safe and effective method of managing pain and anxiety in dentistry. Referred to as “relative analgesia,” “conscious sedation” or “nitrous oxide sedation,” the use of nitrous oxide is increasing in dentistry. Among all dentists, it rose from 35 percent in 1983 to 58 percent in 1991; among pediatric dentists, it increased from 65 percent in 1988 to 88 percent in 1991 (Figure).

Potential benefits of nitrous oxide sedation are well-documented. The dental care team and the patient benefit from reduced stress and increased comfort. The potential disadvantages of using nitrous oxide sedation are few. For the patient, the production of hypoxia is the most significant potential hazard. Adequate training in the administration of nitrous oxide reduces the potential of hypoxia and other adverse patient outcomes. The most significant hazard for the dental care team is the potential adverse health effect of long-term exposure to nitrous oxide.

Effects of chronic exposure to nitrous oxide

Concerns regarding the exposure of health care workers to nitrous oxide in the workplace are addressed in an April 1994 Alert issued by the National Institutes for Occupational Safety and Health. The NIOSH Alert identifies measures for reducing exposure to nitrous oxide and suggests that they be part of each practice’s comprehensive written safety and health plan for workers.

Disorders associated with nitrous oxide exposure. Nitrous oxide inactivates methionine synthase, an enzyme essential for the synthesis of DNA and for the metabolism of vitamin B₁₂, thereby interfering with cellular proliferation. The effects of short-term (acute) nitrous oxide exposure are reversible. Long-term (chronic) exposure to nitrous oxide in sufficient concentrations can produce irreversible, toxic changes, and should be a concern for dental personnel working in environments in which nitrous oxide is administered to patients.

Chronic exposure to nitrous oxide has been associated with reproductive, hematologic, immunologic, neurological, liver and kidney disorders. Symptoms are dose- and time-related, with neurological symptoms most frequently reported in cases of chronic abuse (or recreational use). A retrospective study by Rowland...
and colleagues found decreased fertility in female dental assistants who were exposed to high levels of unscavenged nitrous oxide. For each hour of exposure to unscavenged nitrous oxide, fertility was reduced by 6 percent. Rowland and colleagues did not report a reversal of this reduction after withdrawal from exposure to unscavenged nitrous oxide. The effect required five or more hours of exposure per week. An earlier retrospective study by Cohen and colleagues found a 2.3-fold increase in spontaneous abortion among female chairside dental assistants who were exposed to nitrous oxide. The same study found increased rates of spontaneous abortion among wives of male dentists who were chronically exposed to nitrous oxide (perhaps owing to defective spermatogenesis), a 1.7-fold increase in liver disease among male dentists, and a 1.6-fold increase in liver disease among female dental assistants.

Chronic exposure to nitrous oxide may produce symptoms that mimic those of pernicious anemia or multiple sclerosis. Among the reported neurological symptoms are loss of ability to concentrate, numbness of the extremities, paresthesia, ataxia, impotence, and loss of bladder and bowel sphincter control. The neurological symptoms are dose-related, increasing in both intensity and number with increased exposure.

Hematologic changes associated with chronic exposure to nitrous oxide are a result of bone marrow suppression. The effects are suggestive of pernicious anemia, a vitamin B₁₂ deficiency disease.

Safe and permissible concentrations of nitrous oxide. The maximum safe concentration of nitrous oxide in the health care environment has not been determined. The Occupational Safety and Health Administration has not established a maximum permissible concentration; however, NIOSH has established a recommended exposure limit, or REL, of 25 ppm N₂O during administration. This limit is based on the prevention of adverse reproductive and psychomotor health effects. The American Conference of Governmental Industrial Hygienists, or ACGIH, has established a threshold limit value, or TLV, of 50 ppm for an eight-hour time-weighted average, or TWA. Owing to the lack of consensus in the scientific community, the American Dental Association has not proposed a permissible exposure limit for nitrous oxide in the dental office. Among the methods used to control nitrous oxide in the dental office, the ADA emphasizes the routine use of scavenging equipment.

Nitrous oxide concentrations up to 3,500 ppm have been reported in unsavaged dental operatories. In a 1992 study of both scavenged and unsavaged operatories, Boyer reported a mean occupational exposure to nitrous oxide of 78 ppm TWA for dental hygienists. Forty percent had a TWA above 25 ppm and 33 percent had a TWA above 50 ppm.

Compliance with either the NIOSH or the ACGIH recommendation may be difficult in some clinical settings because of the large number of variables affecting nitrous oxide concentrations in the dental environment.

### SOURCES OF NITROUS OXIDE IN THE DENTAL ENVIRONMENT

Nitrous oxide gas may enter the dental environment from various sources including gas cylinders, gas bottle regulators, exhaust hoods, scavenging systems, gas mixing devices, or through failure and malfunction of equipment.
### Controlling Nitrous Oxide in the Dental Environment

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspect all nitrous oxide equipment for worn parts, cracks, holes or tears.</td>
<td>Replace defective equipment and parts.</td>
</tr>
<tr>
<td>Turn on nitrous oxide tank and check all high-to-low-pressure connections for leaks.</td>
<td>Determine and fix source of leak.</td>
</tr>
<tr>
<td>Select scavenging system and mask. System should operate at airflow rates of up to 45 liters per minute.</td>
<td>Provide a range of mask sizes.</td>
</tr>
<tr>
<td>Connect mask and hose and turn on vacuum pump before turning on nitrous oxide. Scavenging system vacuum must have capacity to scavenge 45 L/min.</td>
<td>Determine proper vacuum pump size for maintaining 45 L/min. flow rate. If undersized, replace.</td>
</tr>
<tr>
<td>Place mask on patient and ensure good fit. Make sure reservoir bag is not over- or underinflated while patient is breathing.</td>
<td>Secure mask with slip ring. Observe reservoir bag.</td>
</tr>
<tr>
<td>Check general ventilation for good air mixing. Exhaust vents should not be close to air supply vents.</td>
<td>If general room air mixing is inadequate, increase the airflow or redesign it. If exhaust vents are close to air supply vents, relocate them.</td>
</tr>
<tr>
<td>Conduct personal sampling of all dental workers at risk.</td>
<td>If personal exposures exceed 150 ppm, improve mask fit and minimize patient’s talking.</td>
</tr>
<tr>
<td>Personal sampling results should not exceed 225 parts per million of nitrous oxide during time of administration.</td>
<td>If personal exposures are less than 150 ppm but greater than 25 ppm, implement auxiliary exhaust ventilation near patient’s mouth.</td>
</tr>
</tbody>
</table>

Adapted from McGlathery JD, Crouch KG, Mickelsen RL.19

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- Unscavenged gas is one of the most significant sources.
- Equipment leaks are another common and significant source of gas. Periodic maintenance and inspection help reduce the potential of gas leakage from equipment.
- Inadequate operatory ventilation contributes to high nitrous oxide levels. Inadequate ventilation may be the result of either a system that fails to exchange sufficient volumes of air or a system that recirculates contaminated air back into the dental environment. Borganelli and colleagues found a significant reduction in ambient nitrous oxide when operatory ventilation rates were increased from five room air exchanges per hour to 10 or 15 exchanges per hour.
- Other potential sources of waste gas are leakage around the periphery of poorly fitting nasal masks and air exhaled by patients during mouth breathing and talking.

### Controlling Nitrous Oxide in the Dental Care Environment

A 1994 Technical Report by NIOSH called “Control of Nitrous Oxide in Dental Operatories” suggested that nitrous oxide concentrations may be consistently controlled at a level of approximately 25 ppm or less during administration by following specific control measures. An eight-step plan to control waste nitrous oxide in the dental operatory is recommended by NIOSH (Box, “Controlling Nitrous Oxide in the Dental Environment”).

A written control plan should be developed specifically for each dental treatment facility. The plan should include the following elements: exposure monitoring, engineering controls, work practices, maintenance procedures and a worker education program.

**Monitoring nitrous oxide concentration.** Monitoring nitrous oxide concentration in the dental environment is the first step in developing a comprehensive control plan. Air samples should be taken from two locations: the workers’ breathing zone and the air outside the breathing zone (room air). NIOSH recommends that den-
tal office personnel perform continuous room air monitoring with an infrared spectrophotometer, mounted centrally in the dental facility. Air in the dental worker’s breathing zone may be monitored with a passive dosimeter attached to the uniform top. Breathing-zone air should be sampled only while nitrous oxide is being administered.

**Engineering controls.**
Engineering controls address the prevention of nitrous oxide leakage from equipment, and the elimination of waste gas from the environment during administration. Nitrous oxide can leak from either the high-pressure or the low-pressure side of anesthetic administering equipment. Ensuring that equipment is installed and repaired only by authorized dealers, and periodically inspected and maintained by office staff, will help protect against leakage.

The proper use of an approved scavenging system will reduce the escape of waste gas in the area of the worker’s breathing zone. A variety of scavenging systems are available for use in dentistry. However, no scavenging system is currently accepted by the ADA Council on Scientific Affairs. (In May 1994, the ADA Council on Dental Materials, Instruments and Equipment voted to rescind the ADA guidelines used in the evaluation of nitrous oxide scavenging systems in the Seal of Acceptance program.)

In an uncontrolled clinical study of the efficacy of five commercially available systems (Ohmeda, Parkell, Brown, Dupaco and Porter), Donaldson and Gabrielsen reported mean background nitrous oxide levels ranging from 43.4 to 62.7 ppm.

The Brown system (43.4 ppm) and Porter system (48.2 ppm) were the most efficient. In another, controlled study of four scavenging systems (Ohmeda, Brown, Dupaco and Porter), Donaldson and Orr\textsuperscript{20} found that all systems tested were capable of reducing nitrous oxide levels below 50 ppm; however, the Porter system measured higher levels than any other.

A flow rate of 45 L/min., measured by an adjustable flowmeter, is the recommended scavenger vacuum rate. The vacuum should be vented to the outside of the building, away from windows and fresh air intakes.

**Ventilation.** Room ventilation should be assessed to ensure adequate air exchange. Among the factors that should be considered are
- the location of fresh air inlets and return vents;
- the location of the ventilation system exhaust;
- the air exchange rate.

Fresh air inlets should be located in the ceiling. Exhaust (return) air vents should be located at floor level. Boranelli and colleagues\textsuperscript{20} found that both operatory ventilation and scavenger evacuation rates had a significant inverse relationship to ambient nitrous oxide levels in a closed operatory. In their study, reductions below the NIOSH recommendation (25 ppm) were achieved with room exchanges of 10 or more per hour. McGlothlin and colleagues\textsuperscript{20} suggested the use of auxiliary ventilation to supplement general ventilation when personal exposures are more than 25 ppm but less than 150 ppm N\textsubscript{2}O.

**Work practices.** Several work practices can reduce the hazards of nitrous oxide. They are described in full in the ADA Council on Scientific Affairs report that follows this article, but I present an abbreviated list here:

- At the beginning of each day, before the anesthetic gas is turned on, inspect equipment to ensure that all connections are tight and that the tubing and reservoir (breathing) bag are free of holes.
- Always use a scavenging system when administering anesthetic gas. Before administering anesthetic gas, turn on the scavenging vacuum and adjust it to a flow rate of 45 L/min.
- Instruct the patient to refrain from mouth breathing and talking during administration of anesthetic gas.
- During administration, observe the breathing bag and adjust the flow rate of anesthetic gas so that the bag does not overfill. The bag should collapse and expand as the patient breathes.
- After administration, flush the system by administering 100 percent oxygen to the patient for at least five minutes.

**Maintenance.** Every dental practice should have an established schedule for periodic inspection (ideally, once every
three months) and a written maintenance plan that includes the following steps:
- Inspect and test all equipment for leaks, beginning with the storage tanks and ending with the scavenging mask. A portable infrared spectrophotometer or a soap solution applied to all fittings and connections may be used to test for leaking nitrous oxide at gas line connections.
- Document the results of inspections and leak tests, as well as all corrective actions taken.
- Ensure that repairs and modifications of equipment are performed only by authorized dealers.

### SUMMARY

Long-term exposure to nitrous oxide is a potential health hazard to personnel in dental offices where nitrous oxide is administered to patients for the control of anxiety and pain. A maximum permissible level of nitrous oxide in the dental environment has not been determined; however, with the implementation of a written control plan, environmental levels within current recommendations by NIOSH (25 ppm REL) and ACGIH (50 ppm TWA) may be achieved.