

Effectiveness of 2 Scavenger Mask Systems for Reducing Exposure to Nitrous Oxide in a Hospital-Based Pediatric Dental Clinic: A Pilot Study

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ABSTRACT

Chronic exposure to elevated ambient air levels of nitrous oxide during nitrous oxide/oxygen (N₂O/O₂) sedation can result in deleterious side effects to dentists and auxiliary staff. A sampling survey was done in the outpatient dental clinic at the Hospital for Sick Children to determine whether airborne nitrous oxide (N₂O) gas concentrations were within established regulatory limits. The effectiveness of 2 scavenger mask systems, the Matrix Medical single-mask system and the Porter/Brown double-mask system, for reducing airborne contamination in a clinical environment during the treatment of pediatric dental patients was compared in a pilot study. The results indicated that the double-mask system more effectively minimized N₂O exposure during N₂O/O₂ sedation of outpatients for a variety of clinical pediatric dental procedures.

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The use of nitrous oxide/oxygen (N₂O/O₂) inhalation for conscious sedation of dental outpatients is generally well accepted as safe.^{1,2} The potential risks of chronic occupational exposure to ambient levels of nitrous oxide (N₂O) are well documented.^{3,4} Occupational exposure standards are set in Ontario in Regulation 833 under the provincial Occupational Health and Safety legislation called Control of Exposure to Biological or Chemical Agents. In addition, Ontario Regulation 67/93, the Healthcare and Residential Facilities Regulation, that governs the conduct of N₂O/O₂ sedation states that health care facilities must install “effective scavenging systems to collect, remove and

dispose of waste gases” when any anesthetic gas is used.⁵

Scavenging systems generally use a vacuum or suction apparatus, either directly connected to the anesthetic equipment or placed near the patient, to collect all expired or waste anesthetic gases in an operating room, recovery room or dental clinic. Scavenging equipment is used in addition to effective ventilation or airflow in the clinical environment. Some hospital scavenging equipment can be quite large and external to the anesthetic equipment (**Figs. 1a** and **1b**). Scavenging equipment used for N₂O/O₂ sedation consists of a vacuum attached to the nasal mask or through the exhaust hose.⁶⁻¹² This equipment recovers



Figure 1a: In some hospital settings, scavenging systems that are external to the anesthetic equipment may be used to collect waste anesthetic gases.



Figure 1b: In some recovery rooms, hoods such as the one pictured here connected to a vacuum are used to collect waste anesthetic gases after anesthetic procedures.



Figure 2: The Matrix Medical single-mask scavenging system in place with the external valve scavenging core.

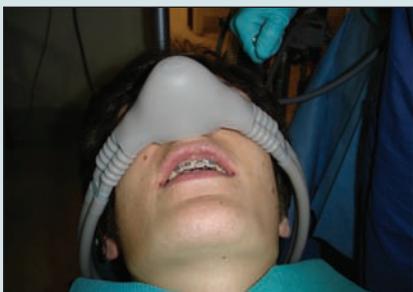


Figure 3a: The Porter/Brown double-mask scavenging system in place.

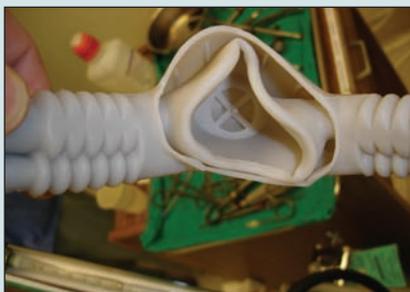


Figure 3b: The inner aspect of the Porter/Brown double mask showing the internal and external mask. The relief valve is connected to the internal mask and allows the release of the expired gases into the external mask. The external mask is connected to 2 hoses that are directly connected to a suction system for evacuation of the gas.



Figure 4: The Miran Sapphire infrared spectrometer used for air sampling to determine nitrous oxide levels in this study.

the expired waste gases by constant suction, transferring gases for dilution to an external environment (Figs. 2, 3a and 3b). Evaluation of the ability of scavenging systems to reduce operators' and auxiliary staff's exposure during N_2O/O_2 sedation has demonstrated that not all systems are equally effective.⁶⁻¹⁵ The Porter/Brown scavenger mask system (Porter Instrumentation Company, Hatfield, Penn.) achieved a greater reduction in ambient N_2O levels than other systems when tested during a standardized mock dental treatment protocol designed to reflect clinical practice.¹⁵ However, continuous or real-time monitoring of N_2O levels for occupational exposure limits in an actual pediatric clinical environment has not been evaluated.

The Ontario occupational exposure limit for N_2O is 25 ppm.¹⁶ The occupational exposure limit is defined as the average airborne concentration of a chemical agent to which a worker or clinical staff member can be exposed daily, based on an 8-hour working day and a 40-hour work week. This limit is believed to be the maximum concentration of a substance that nearly all workers may

repeatedly be exposed to day after day without adverse health effects. Best practice for occupational hygiene, however, is to establish action levels that are 50% of the occupational exposure limits to provide a margin of safety to prevent meeting or exceeding the occupational exposure limit.¹⁶

The purpose of this study was to measure the N_2O levels in the ambient air of a pediatric treatment room and to compare how effectively 2 scavenger mask systems, a single-mask and a double-mask system, minimized operators' and auxiliary staff's exposure to ambient N_2O gas levels in a hospital-based pediatric dental clinic. Mask effectiveness was assessed with samples of airborne N_2O gas concentrations taken during actual sedations of pediatric outpatients to determine whether the concentrations were within established government limits.

Materials and Methods

This study was conducted in the outpatient dental clinic at the Hospital for Sick Children in Toronto,

Table 1 N₂O concentrations with single nasal mask system

Procedure	Length (min)	Mask type	Concentration of N ₂ O averaged over a procedure (ppm)	N ₂ O TWAEV (ppm)
Restorations and sealant	80	P	30.1	5.0
Restorations	71	P	82.9	12.3
Extractions	27	P	22.9	1.3
Restorations	80	A	12.2	2.0
Extractions	76	A	64.8	10.3
Surgical placement of 4 dental implants	96	A	188.8	37.8

A = adult mask; P = pediatric mask; TWAEV = time-weighted average exposure value.

Table 2 N₂O concentrations with the Porter/Brown mask system

Procedure	Length (min)	Mask type	Concentration of N ₂ O averaged over a procedure (ppm)	N ₂ O TWAEV (ppm)
Extractions	30	A	38.1	2.4
Extractions	35	A	106.0	7.7
Extractions	35	A	88.3	6.4
Restorations	35	A	5.5	0.4
Extractions	56	A	21.6	2.5
Extractions	33	P	11.2	0.8
Restorations	47	P	9.1	0.9
Extractions	51	P	19.3	2.1
Extractions	43	P	15.9	2.2
Extractions/restorations	45	P	17.9	1.7
Extractions/dental implants	119	P	39.1	9.7

A = adult mask; P = pediatric mask; TWAEV = time-weighted average exposure value.

Ontario. N₂O/O₂ was administered for a variety of dental procedures. All 17 patients who participated in the study were cooperative throughout the time that N₂O/O₂ sedation was administered. Administration of N₂O and completion of the dental procedures were done by staff oral and maxillofacial surgeons, staff pediatric dentists, and residents or fellows.

One of 2 scavenger mask systems was used: 1) a single nasal-mask system (6 patients) (**Fig. 2**: Matrix Medical, Orchard Park, N.Y.) that consisted of an external valve scavenging core connected to a suction system to permit evacuation of waste N₂O gas and 2) a double nasal-mask system (11 patients) that consisted of a liner and an outer shell (**Figs. 3a** and **3b**: Porter/Brown Scavenging Mask). The double-mask system uses a scavenging mechanism with a relief valve connected to the internal mask that allows release of the scavenged N₂O to the external mask.

The external mask contains 2 hoses that are directly connected to a suction system for the evacuation of waste gas. Exactly the same negative pressures were used for both scavenging systems. The vacuum pressures were not altered at any time during the conduct of the study.

A Miran Sapphire direct air-sampling instrument (Thermo Electron Corporation, Waltham, Mass.) was used to measure N₂O levels of the ambient air in the treatment room (**Fig. 4**). The sampling port was located 1.0 to 1.5 metres away from the patient, as close as practicable to the breathing zone of the dentist and auxiliary staff. The Miran instrumentation uses infrared spectrometry to measure N₂O concentrations with an accuracy of 0.04–100.00 ppm ± 10%. Measurements of real-time N₂O concentration were recorded on the instrument and subsequently downloaded to a computer for analysis. The same operatory was used to test both systems, and exactly

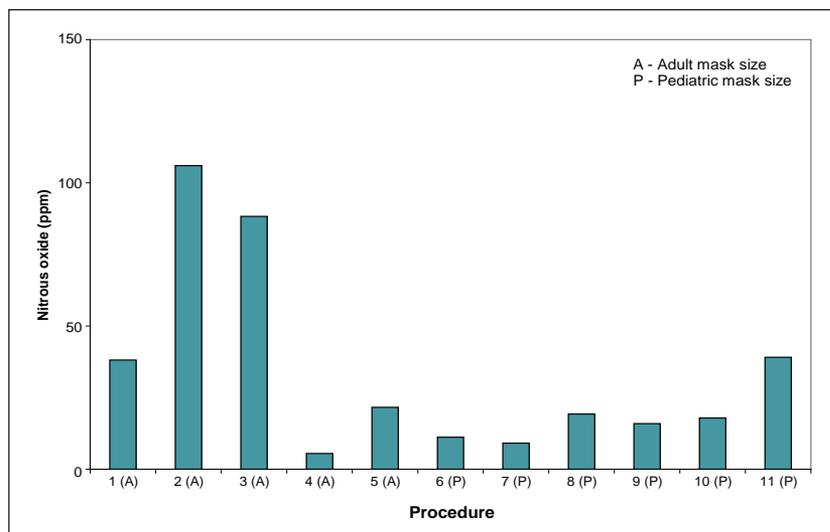


Figure 5: Nitrous oxide levels in ambient air averaged over a procedure with the double-mask scavenging system.

the same air-exchange conditions were present during the testing of both scavenging systems. Only 1 treatment involving N₂O/O₂ sedation of a patient was done in the study operatory during each 8-hour day.

Measured concentrations of N₂O averaged over the procedure were used to calculate the time-weighted average exposure value (TWAEV), which is defined as the average of the airborne concentrations of a chemical agent determined from air samples to which a worker is exposed in a work day or work week.¹⁶ The following equation was used to calculate TWAEVs:

$$\text{TWAEV} = (\sum \text{cntn}) / 8 \text{ hours}$$

where c = concentration found in an air sample and t = total time in hours to which the worker is exposed to the concentration

For the calculation of the TWAEV, it was assumed that no other exposures to N₂O occurred for the remainder of the day.

Results

Ambient N₂O levels measured with the use of the single and double nasal-mask scavenger systems are summarized in **Tables 1** and **2**, respectively. The results are expressed as concentrations of N₂O in parts per million averaged over the duration of a procedure.

The TWAEVs for both types of scavenger mask systems are summarized in **Tables 1** and **2**. The tables show that higher airborne N₂O levels were measured with the use of the single nasal-mask system than those obtained with the double nasal-mask system. **Table 1** shows that N₂O levels exceeded the occupational exposure limit during 1 procedure and approached the action limit during

2 procedures. Concentrations of N₂O would have exceeded the daily exposure limit if more than 1 procedure had been done on any given day with the single-mask scavenging system.

Figure 5 shows the concentration of N₂O averaged over a procedure done with the double-mask scavenging system. The first 5 procedures, which were carried out with an adult-sized mask, showed elevated levels of ambient N₂O. The remaining procedures were carried out with a pediatric-sized mask, and the concentration of N₂O was consistently low.

Discussion

Clinicians and auxiliary staff must be given the maximum possible protection from potential long-term health problems associated with chronic N₂O exposure. Therefore, it is imperative to ensure that the N₂O scavenging equipment installed in hospitals or dental offices maintains N₂O exposure levels in the ambient air below established standards. The results of this study demonstrate that lower airborne N₂O levels are attained with the use of the double-nasal mask scavenging system than with the single-mask scavenging system. In addition, proper mask size was also an important factor in the reduction of waste N₂O levels in the ambient air of the treatment room.

A previous study¹⁵ comparing the 2 nasal mask scavenging systems, with similar results, used a mock protocol designed to reflect dental practice rather than an actual clinical treatment situation as in our study. As in our pilot study, a report by Chrysikopoulou and others¹⁷ also compared the effectiveness of 2 different mask scavenging systems in actual pediatric dental treatments and found the double-mask system to be superior. Lower ambient air levels of N₂O were measured consistently with the double-mask system.

Dentists and specialists who provide N₂O/O₂ sedation must be aware of the standards that exist in their practice jurisdictions. Monitoring N₂O levels in ambient air is recommended to ensure that exposure limits are observed. Dental practitioners can minimize the risk of exposing staff to N₂O by ensuring selection of the correct mask size for each patient, continuous monitoring of the mask seal to the patient's face during clinical treatment and turning off the N₂O supply well in advance of removing the nasal mask. In addition, inspecting all aspects of the N₂O/O₂ delivery system for wear and tear before each use and testing the system for leaks on a monthly basis will aid in the reduction of staff's exposure to N₂O.

Safe practice techniques also dictate that the clinician keep the concentration of N₂O given to patients as

low as possible. Higher concentrations of N₂O may be given to the patient during the more stressful parts of a procedure, such as during the administration of local anesthesia. N₂O concentrations can then be decreased at less stressful times during the treatment and turned off when no longer required before the end of the procedure. The patient should be encouraged to exhale through the nose and not the mouth at all times during N₂O/O₂ sedation to maximize the collection of waste anesthetic gases by the scavenging equipment. In addition, N₂O supplied to the patient should be turned off while the mask is still on the patient and only oxygen given to the patient once the procedure is complete. This practice ensures that any N₂O still left in the patient is exhaled into the scavenging system and not into the room.

This study had a number of limitations. The sample size was small, which is the reason that we refer to this study as a pilot study. With our evidence of the increased benefit of a double-mask scavenging system over a single-mask system, hospital internal ethics boards are unlikely to approve further similar studies with patients. However, we hope that this study will encourage further future large-scale study of the effectiveness of scavenging systems funded by their manufacturers. Also, many variables were not controlled for in the current study, including patient cooperation variables such as mouth breathing, talking and crying; precise mask fit; procedure type; and age of the patient. These variables should be more closely controlled for in a larger prospective study. From a clinical point of view, these limitations underscore the need for proper patient selection for cooperation with this sedation technique. A patient who is unable to cooperate with instructions about breathing into the scavenging system or who cries uncontrollably may place the dentist and auxiliary staff at risk for exposure to higher than necessary ambient levels of N₂O.

It is important to ensure that the mask scavenging equipment used for the administration of anesthetic gases can efficiently keep ambient N₂O levels well below legislated limits. ♦

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