Effectiveness of Two Nitrous Oxide Scavenging Nasal Hoods During Routine Pediatric Dental Treatment

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Abstract

Purpose: This study compared the effectiveness of 2 nasal hoods (Porter/Brown and Accutron) in reducing waste nitrous oxide gas during conscious sedation for routine pediatric dental treatment.

Methods: Thirty children, ages 3 to 8 years (mean=5.4±1.2 years), participated in this study. Fifteen randomly selected children started with the Porter/Brown mask, which was then switched to the Accutron mask, and the other 15 children used the reverse order of masks. Four measurements of ambient nitrous oxide were recorded with a Miran 205B Portable Ambient Air Analyzer 5 minutes after each of the following: (1) administration of nitrous oxide; (2) placement of the rubber dam; (3) change of the nasal hood; and (4) reduction of the vacuum. Samples were taken 8 inches above the nose of the patient and in the room 5 feet away from the patient.

Results: Nitrous oxide levels were significantly lower (P<.05) with the Porter/Brown system (31±40 ppm for the patient and 8±10 ppm for the room) compared with the Accutron system (375±94 ppm for the patient and 101±37 ppm for the room). When the suction was reduced, there was an increase in nitrous oxide levels with the Porter/Brown nasal hood (169±112 ppm for the patient and 28±18 ppm for the room), whereas the levels with the Accutron nasal hood remained high (368±107 ppm for the patient and 121±50 ppm for the room).

Conclusions: This study demonstrated that removal of waste nitrous oxide was greater with the Porter/Brown device and that recommended suction levels must be used for optimum effectiveness. (Pediatr Dent 2006;28:242-247)

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Chronic exposure to waste anesthetic gas has caused health concerns for individuals involved in the field of general anesthesia and dentistry. In 1967, Vaisman[1] surveyed almost 300 anesthesiologists in Russia and reported an unusually high prevalence of headache, fatigue, and irritability. He also noted that a high percentage of the pregnancies among female anesthesiologists ended in spontaneous abortion. Cohen et al[2] sent questionnaires requesting information regarding health history and number of hours per week exposed to anesthetic gases. He sent the questionnaire to 4,797 general dentists and 2,798 oral surgeons and found a significant relationship between the incidence of health problems, such as spontaneous abortion and liver disease and exposure to the waste anesthetic gases. Bruce and Bach found that subjects had impaired performance produced by enflurane and by 500 ppm nitrous oxide when given as the only anesthetic.[3] In 1976, they conducted a second study[4] to establish the limit of exposure at which performance decrements were undetectable. They found that nitrous oxide and halothane, 50 ppm and 1 ppm respectively, caused decreased performance on psychological tests. This did not occur in subjects exposed to nitrous oxide 25 ppm and halothane 0.5 ppm. Cohen et al conducted another study[5] in which they sent questionnaires to 30,650 dentists and 30,547 assistants. They found that long-term

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exposure of male dentists to nitrous oxide might result in an increased incidence of liver disease, spontaneous abortion in their wives, renal lithiasis, and neurological disease, with analogous disease rates for female chairside assistants. Rowland et al[6] confirmed the association between occupational exposure to unscavenged nitrous oxide for 5 or more hours per week and reduced fertility.

There are 2 agencies that have established appropriate levels of occupational exposure to nitrous oxide: (1) the American Conference of Governmental Industrial Hygienists (ACGIH); and (2) the National Institute for Occupational Safety and Health (NIOSH). These agencies concluded that nitrous oxide exposure resulted in decreased mental performance, audiovisual acuity, and manual dexterity. To prevent these effects, a 25 ppm exposure limit was recommended[7] based on studies by Bruce,[4] who stated that acute exposure to nitrous oxide (50 ppm) produced a measurable decrease in performance in a psychological test in healthy adult male volunteers. In October of that same year, an Ad Hoc Committee of the American Dental Association published a report entitled Trace Anesthetics as a Potential Health Hazard in Dentistry.[8] The Committee recognized the potential of a health hazard occurring and that "every effort should be made to reduce the trace concentration of anesthetic/sedative agents in the dental environment." In 1994, NIOSH established upper-limit guidelines for environmental nitrous oxide exposure.[9] These guidelines stated 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 concentrations greater than 25 parts per million (ppm) during anesthetic administration." The American Conference of Governmental Industrial Hygienists (ACGHI), however, established a threshold limit value for nitrous oxide exposure that differed from NIOSH's. In 1989, the ACGIH recommended a nitrous oxide threshold limit value (TLV) of 50 ppm for an 8-hour exposure.[10]

Because nitrous oxide can be a potential occupational health hazard, levels in dental operatories were evaluated. Whitcher[11] found that the levels of nitrous oxide with a conventional mask were 900 ppm, compared to 31 ppm when a scavenging mask was used. Tonn and Whitcher found also that the scavenging mask was successful in reducing the nitrous oxide gas in the dentist's breathing zone from 940 ppm to 33 ppm.[12] With the addition of a small fan, the levels were further reduced to 9.4 ppm. Henry and Jerrell[13] studied nitrous oxide levels during conscious sedation with chloral hydrate and hydroxyzine. The scavenging system significantly reduced the concentration of waste nitrous oxide, but did not approach the National Institute of Occupational Safety and Health's (NIOSH) recommended limit. Henry and Primosch[14] also found that with pediatric dental treatment, scavenging reduced ambient nitrous oxide levels approximating the 25 ppm NIOSH recommendation. They also concluded that operatory size did not influence ambient nitrous oxide. Henry et al[15] compared scavenging vs nonscavenging masks with different nitrous oxide concentrations. They found that scavenging significantly reduced the levels of nitrous oxide (from 285 to 37 ppm) and that different concentrations resulted in different mean ambient levels of nitrous oxide.

During the last 3 decades, scavenging devices have been introduced to reduce the levels of anesthetic gases in the clinical environment. There are, however, some masks that are more efficient than others in maintaining low levels of nitrous oxide. Christensen[16] compared 2 different scavenging units (Brown, Fraser Harlake) in 10 adult volunteers. He found that the Brown scavenging mask was more effective and that neither the rubber dam nor the patient's talking significantly affected the levels of nitrous oxide.

Donaldson and Orr[17] compared 4 nitrous oxide scavenging systems (Dupaco, Brown, Fraser Harlake, Porter) on 6 healthy adult volunteers and found that the Dupaco mask was the most effective. All systems were capable, under ideal conditions, of controlling levels of nitrous oxide to below 50 ppm. The logical extension of that investigation was to record the efficiency of the systems under various clinical operating conditions. Therefore, Donaldson and Grabi[18] compared 5 nitrous oxide scavenging systems (Brown, Porter, Parkell, Dupaco, Fraser Harlake) in 10 dental offices and concluded that the Brown mask was the most effective. All systems provided good scavenging efficiency, although the achieved levels were not always below the recommended 50 ppm. Certosimo[19] compared 3 nitrous oxide scavenging nasal hoods (Porter/Brown, Accutron, Matrx) in 12 healthy adult volunteers with 3 different concentrations of nitrous oxide. The Porter/Brown scavenger system levels were significantly lower than either the Matrx or the Accutron during mock dental treatment.

Various studies compared different scavenging masks in adults. No study, however, evaluated the effectiveness of the Porter/Brown and Accutron scavenging systems for dental treatment with pediatric patients. This study compared the effectiveness of 2 nitrous oxide scavenging hoods, Porter/Brown and Accutron, in reducing waste nitrous oxide gas when they were used for the administration of conscious sedation for pediatric dental treatment.

Methods

This study was approved by the Institutional Review Board of the University of Medicine and Dentistry of New Jersey (UMDNJ), Newark, NJ. Thirty children (22 males, 8 females) ranging in age from 3 years to 8 years (mean age=5.4±1.2 years) were selected for the study sample. All patients were actively undergoing dental treatment at the UMDNJ-New Jersey Dental School Department of Pediatric Dentistry clinic and had been selected for restorative treatment under nitrous oxide/oxygen conscious sedation by their treating doctor prior to enrollment in this study. Written consent was obtained from the parent/guardian following explanation of the procedure.

Nitrous oxide/oxygen was administered with 1 of 2 randomly assigned nitrous oxide scavenger masks (Porter/Brown, Porter Instrument Company, Inc, Hatfield, Pa, and Accutron, Accutron, Inc, Phoenix, Ariz) at a standard flow rate of 50% nitrous oxide, 3 L/minute. At

each time of measurement, the nitrous oxide levels were recorded for the patient, 8 inches above the patient's nose. The room ambient nitrous oxide levels were recorded at a standard location, 5 feet away from the patient and 2.5 feet from the floor. All levels of nitrous oxide were recorded with Miran 205B portable ambient air analyzer (an infrared spectrophotometer, Foxboro Company, Foxboro Mass). The Miran analyzer was extremely sensitive and took at least 1 minute to register a range of stable readings. The reported readings were the average of the range's high and low number used to report the score.

Four measurements were recorded. The first measurement was taken 5 minutes after the administration of nitrous oxide. The second measurement was taken 5 minutes after rubber dam placement. The scavenger nasal hood was then changed to the second nasal hood, and after 5 minutes the third measurement was taken. Finally, the scavenging unit's suction was reduced to half power, and after 5 minutes the forth measurement was taken. The extra time needed for the study was less than 1 minute.

The same operatory room was used throughout the study, and its size was 11×12×9 feet. The door was closed during the experiment, and the air supply and exhaust were operational. Prior to the start of each session, the room air was evaluated using the infrared spectrophotometer to assure that the baseline value of nitrous oxide in the operatory approached zero.

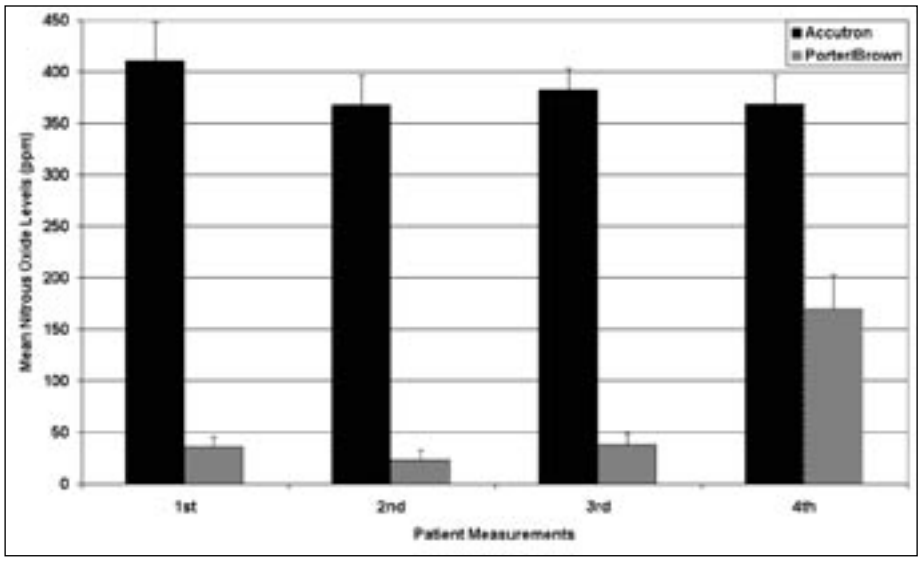

Figure 1. Nitrous oxide concentration for patient measurement. P<.001 for comparisons at all 4 measurements.

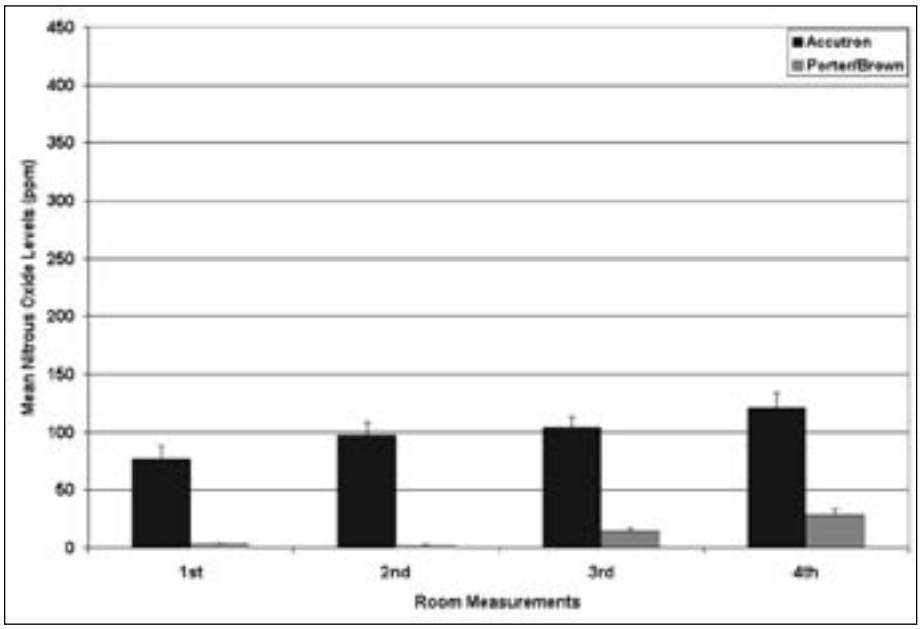

Figure 2. Nitrous oxide concentration for room measurement. P<.001 for comparisons at all 4 measurements.

Data analysis

The dependent variable in this study was the concentration of the nitrous oxide (in ppm). The independent variable was the type of scavenging nasal hood (Porter/Brown vs Accutron). Other independent variables were the use of rubber dam and the scavenging unit's suction level.

Dependent *t* tests were used to test the difference in nitrous oxide between the two nasal hoods with patients serving as their own controls. For comparisons within the same hood given during the first part of the experiment vs. the second part, independent *t* tests were used. All statistics were computed using SAS (SAS Institute, Inc, Cary, NC). A priori alpha was set at 0.05.

Results

This study's results appear in Figures 1 and 2. Mean levels of nitrous oxide (ppm) are reported for each of the 4 measurement time periods for both the Accutron and Porter/Brown nasal hoods. The sample size for each measurement time period was 15, with the exception of period 4—when it was 14 for Porter/Brown and 11 for Accutron. This was due to the short length of clinical procedures, which precluded the fourth measurement for 5 of the 30 subjects.

In each Figure, the values reported for measurements 1 and 2 were when the nasal hood was used at the start

Figure 3a. Porter/Brown scavenging nasal hood—front outside view.

of the procedures, and the values for measurements 3 and 4 were when the particular nasal hood was used for the second half of the procedure after the hood was changed. For all measurements, there was relatively large variability leading to large standard deviations around the mean scores. Nevertheless, with the Porter/Brown nasal hood, the nitrous oxide levels were statistically significantly lower than with the Accutron nasal hood (P<.001) for patient and room measurements. For each of the patient measurements with the subjects using the Accutron mask, the mean values were 410±148, 368±109, 382±81 and 368±107 ppm compared with 36±36 ppm, 23±37 ppm, 38±43 ppm, and 169±112 ppm when the Porter/Brown mask was used. For the room measurements, the mean values were 77±43 ppm, 97±42 ppm, 104±33 ppm, and 121±50 ppm with the Accutron mask, compared with 3.5±3.7 ppm, 2.1±1.9 ppm, 14±12 ppm, and 29±18 ppm with the Porter Brown mask.

Since the nasal hood was changed after the second measurement and before the third measurement, a comparison of values obtained at measurements 2 and 3 would indicate if there was any order effect—that is, a difference if the hood type was used first or second (Figures 1 and 2). For patient measurements, there were no statistically significant differences between measurements 2 and 3 (Accutron=368±109 ppm vs 382±81 ppm, P=.7; Porter/Brown=23±37 ppm vs 38±43 ppm, P=.35). For room measurements, there were no statistically significant differences with the Accutron mask (97±42 ppm vs 104±33 ppm, P=.65). The differences in room measurements with the Porter/Brown mask, however (2.1±1.9 ppm vs 14±12 ppm), were statistically significant (P<.05). This might be explained by residual nitrous oxide near the patient and in the room following use of the Accutron nasal hood for the first half of the procedure.

The rubber dam's influence was indicated by comparison of the first and second measurements (Figures 1 and 2). With the Porter/Brown scavenging system, there was no significant difference in the levels of ambient nitrous oxide whether or not a rubber dam was placed in the mouth (patient measurement=36±36 ppm vs 23±37 ppm; room measurement=3.5±3.7 ppm vs 2.1±1.9 ppm). With the Accutron system for patient measurements, there was no statistically significant difference between measurements 1 and 2 (410±148 ppm vs 368±109 ppm). For room measurement, however, there was a significant increase when the rubber dam was placed (77±43 ppm vs 97±42 ppm). This might have been due to the method of measurement in that the first room measurement was performed when the mouth was closed (5 minutes after the administration of nitrous oxide), whereas the second room measurement followed local anesthesia administration when the mouth was open. In addition, ambient nitrous oxide was in the air. When the levels are so high, it takes longer for the room to be evacuated by the ventilation system. Therefore, even though the second room measurement was performed 5 minutes after the rubber dam application, the nitrous oxide levels in the room likely were still high.

The influence of the amount of suction was indicated by comparison of the third and fourth measurements (Figures 1 and 2). The Porter/Brown subjects demonstrated statistically significant increases for the nitrous oxide levels when reduced suction was used. For patient measurements, the difference with the Porter/Brown mask was statistically significant between measurements 3 and 4 (38±43 ppm vs 169±112 ppm; P<.05). For room measurements, the difference was also statistically significant (14±12 ppm vs 29±18 ppm). In comparison with the Accutron system the levels of nitrous oxide were unaffected when the suction was reduced (patient measurement=382±81ppm vs 368±107 ppm; room measurement=104±33 ppm vs 121±50 ppm). This might be explained by the fact that high levels of nitrous oxide were in the room even when the suction was normal.

Discussion

Nitrous oxide scavenger devices are commonly used by pediatric dentists. There is little evidence, however, to demonstrate that those devices are being used appropriately and are effective. Previous studies indicated that the Porter/Brown scavenger system was more effective than other systems.[16-20] No study, however, examined the effectiveness of the Porter/Brown with the Accutron devices in actual pediatric dental treatment.

In this study, the Porter/Brown scavenging system was found to be more efficient than the Accutron system. The most significant finding, however, was the markedly high levels of nitrous oxide when the Accutron system was used. The nitrous oxide levels were high, not only in the area where the dental treatment was performed, but also in the entire dental operatory room. In comparison, the Porter/Brown system reduced the occupational exposure of nitrous oxide to acceptable levels, meeting the 25 ppm requirements set by the National Institute of Occupational Safety and Health.[9]

A possible explanation for the significant difference in the efficiency of the 2 nasal hoods can be found in the different designs of the masks. The Porter/Brown mask has 2 separate chambers (Figure 3), where the outer chamber covers the entire inner nasal hood and there is a negative suction surrounding the entire periphery of the mask. In comparison, the Accutron has an outer scavenging cap, which is perched on top of the single nasal hood (Figure 4). Regarding the mask's fit, the adaptation of the Porter/Brown mask appeared to be better than the Accutron mask. It appears that nitrous oxide can escape easier with the Accutron mask than with the Porter/Brown mask. The escaped gas could pass into the air and not be suctioned by the scavenging cap at the top of the mask.

The present study also evaluated the effect of the degree of suction on scavenging ability. There was a significant correlation between the ambient nitrous oxide levels and the suction when the Porter/Brown scavenging system was used. The Porter/Brown subjects demonstrated statistically significant increases in the nitrous oxide levels for both room and patient readings when reduced suction was used. Therefore, the vacuum system-scavenging unit must be operating at the recommended flow rate of 45 L/minute when nitrous oxide is administered to the patient. On the other hand, with the Accutron system the levels of nitrous oxide were unaffected when the suction was reduced. This might be explained by the difference in the design of the Accutron system mask, or the relatively high readings with full suction.

When the Porter/Brown was the second mask used, the nitrous oxide levels were higher than the levels when this mask was used first. This was due to high levels of nitrous oxide that were still in the room after the Accutron system was in use. Even when the mask was changed, it took more time for the nitrous oxide to evacuate from the room. An unexpected finding of this study was the apparent increased depth of sedation with the Accutron mask. Two patients vomited after administration of nitrous oxide with the Accutron scavenging hood, and 1 patient vomited with the Porter/Brown mask just after the switch from the Accutron mask. The investigator also reported dizziness and numbness of the lips. Co-investigators (dentists and dental assistants) reported that they could smell the nitrous oxide when the Accutron system was used, whereas this was not reported with the Porter/Brown system.

In contrast, patients seemed to prefer the Accutron mask, since it comes with different flavors and colors. It would be advantageous if the Porter/Brown system was manufactured with different flavors and more favorable colors. Since the levels of nitrous oxide were significantly higher with one system that is commonly used in pediatric dental operatories, those levels should be measured in private dental offices in future studies. In this study, only 2 different scavenging systems were compared. Future studies should examine the effectiveness of other scavenging nasal hoods used in pediatric dentistry.

Figure 4a. Accutron scavenging nasal hood—front outside view.
Figure 4b. Accutron scavenging nasal hood—back inner side.

Conclusions

Based on this study's results, the following conclusions can be made:

1. Scavenging nasal systems differ in their ability to remove waste nitrous oxide when nitrous oxide conscious sedation is administered to pediatric dental patients. The Porter/Brown system was more effective than the Accutron system.
2. When ambient nitrous oxide levels are higher than recommended safe levels, the levels are high surrounding the patient's face, and they are also high in the room some distance from the patient.
3. Scavenging systems must be operated with the recommended amounts of suction to function effectively.

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