Scientific Article

Effect of scavenging on the psychomotor and cognitive function of subjects sedated with nitrous oxide and oxygen inhalation

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Abstract

Maximizing scavenger effectiveness using a 45 L/min evacuation rate as recommended by the National Institute of Occupational Safety and Health (NIOSH) may alter the sedation level of the dental patient. The purpose of this pilot study was to determine if scavenging at the recommended NIOSH evacuation rate reduced psychomotor and cognitive impairment as a result of inhaling nitrous oxide. Computer-administered neurobehavioral tests of human psychomotor and cognitive function previously established in controlled trials to be sensitive to nitrous oxide inhalation were employed in this blind, randomized, crossover study of 30 healthy adult subjects. The results indicated that scavenging produced statistically significant improvement in finger-tapping speed, symbol/digit coding speed, and recall accuracy. Hand/eye coordination was not improved significantly by scavenging. Enhancement of psychomotor skills and cognitive functioning was interpreted as an undesirable side effect of scavenging that could potentially influence dental patient anxiety management when using nitrous oxide inhalation. The results of this pilot study suggested that scavenger operation under the conditions tested could reduce the level of psychosedation achieved with nitrous oxide inhalation. (Pediatr Dent 19:480–83, 1997)

Nitrous oxide/oxygen inhalation psychosedation is a widely practiced adjunct to anxiety management of dental patients.[1] Exposure of dental personnel to ambient nitrous oxide in the dental operatory, however, may have adverse consequences. Acute exposure creates documented short-term effects on psychomotor performance and cognitive ability, and chronic exposure in dental personnel is implicated in producing long-term effects such as kidney and liver disease, neurological disorders, and reproductive problems.[2,3] Scavenging devices are effective in reducing ambient levels of nitrous oxide from the breathing zone of dental personnel[2,4] and their use is mandated by the American Dental Association (ADA).[5,6]

The method of nitrous oxide scavenging in the dental operatory recommended by the National Institute of Occupational Safety and Health (NIOSH)[7–9] involves connecting suction tubing with an evacuation flow rate of 45 L/min directly to the nasal hood assembly of the nitrous oxide inhalation equipment. Borganelli and coworkers[10] concluded that increasing scavenger evacuation rates produced reciprocal decreases in ambient nitrous oxide levels in the dental operatory. Crouch and Johnston[11] demonstrated that nitrous oxide concentrations within the nasal hood, however, can be reduced significantly with increasing scavenger evacuation flow rates. Maximizing scavenger effectiveness using NIOSH's recommended 45 L/min evacuation rate may reduce the sedation level of the dental patient. This effect may lower the efficacy of traditionally practiced nitrous oxide inhalation, which uses 30–50% nitrous oxide concentrations at a 6–10 L/min total flow rate.

The use of a computer-administered neurobehavioral evaluation system (NES) designed by Baker and coworkers[12,13] has been shown to be a reliable measure of the psychomotor and cognitive impairment induced by nitrous oxide inhalation.[14,15] This system was developed for epidemiological field studies of human populations exposed to neurotoxic agents in the workplace or general environment. The system collects standardized neurobehavioral data with minimal interaction between examiner and test subject. Several studies have highlighted the benefits of NES to include ease of use, standardization of procedures, reduced potential for bias, high subject acceptance, and extreme precision and sensitivity in response measurement.[12–15] Improved psychomotor and cognitive performance on these computer-administered tests might reveal any potential undesirable side effect of nitrous oxide scavenging upon dental-patient anxiety management. This pilot study proposed to determine if scavenging reduced the psychomotor and cognitive impairment obtained by adult subjects inhaling 50% nitrous oxide with oxygen while performing standardized, computer-administered neurobehavioral tests.

Methods and Materials

Healthy adult volunteers were recruited from the

University of Florida College of Dentistry personnel. Subjects completed a medical history questionnaire, signed a consent form to participate, and were paid for their participation. Any subjects taking prescription medications or requiring special health care needs were excluded from the study. All female subjects provided a negative result on a pregnancy test, provided at no cost to the subject, taken within 3 days of participation in the study. The procedures, possible discomforts or risks, and possible benefits were fully explained to the human subjects involved in the study as approved by the University's Institutional Review Board.

Psychomotor and cognitive tests were conducted using the computer-administered NES and software developed by Baker and coworkers.[12, 13] Subjects responded to the automated tests on a portable microcomputer using a joystick controller and two buttons. The three specific NES tests chosen for inclusion in this study were previously shown to be sensitive to nitrous oxide-induced impairment at concentrations of 20[14] and 40%[15] nitrous oxide delivered via the same inhalation scavenging mask system and in a similarly aged population as selected for this study. These specific tests are described below according to their order of administration in this study.

Finger-tapping test

This is a simple test of motor quickness which requires subjects to tap a button as many times as possible in 10 s under three different conditions (dominant index finger, nondominant index finger, alternating index fingers). Data are recorded as the mean number of taps in two consecutive 10-s trials.

Hand/eye coordination test

This test of hand/eye coordination and dexterity requires subjects to trace patterns in a vertical direction with a joystick controller as a cursor moves horizontally across the screen at a constant rate of speed. Subjects trace both a sine wave and a sawtooth pattern. Vertical deviations from the pattern are measured at 300 separate points. The overall measure of hand/eye coordination is the root mean square error of these 300 individual data points.

Symbol/digit substitution test

This test of psychomotor coding speed requires subjects to refer to nine pair of symbols and digits displayed at the top of the computer screen in order to match the digits to a set of scrambled symbols at the bottom of the screen. The mean time (in seconds) to match the digits to the symbols and the number of incorrect responses are recorded for five consecutive trials. The final measure of coding speed is the mean for the best two trials. Coding recall is evaluated using a separate trial where the subject must recall the correct digit matched with the symbol without the aid of the symbol/digit pairs provided on the screen. Recall speed is measured as the mean time to match the digits and symbols, and recall accuracy is the number of correct matches.

These tests of psychomotor and cognitive function were repeated as three separate trials and conducted under experimental conditions lasting 1 h. The first trial was a training/practice session in which subjects breathed 100% oxygen via nasal hood to familiarize them with the computer-administered tests. The order of the second and third trials was randomized with subjects breathing 50% $N_2$0/50% oxygen via nasal hood either with or without scavenging. In the trial without scavenging, the evacuation system was turned on but was disconnected to produce a noise level similar to that for the trial with scavenging. The subjects were blinded to the test condition for the second and third trials. There was a 10-min interval between each trial.

The only commercially available, American Dental Association- (ADA) approved scavenger mask (Porter/Brown, Porter Instrument Co., Hatfield, PA) was used for this study. The rotameter of the in-line vacuum control block (Model 5450A, Porter Instrument Co., Hatfield, PA) of the scavenging system was adjusted with an in-line flowmeter (Porter Series Model 150 Flowmeter, Porter Instrument Co., Hatfield, PA) to produce a 45 L/min evacuation flow rate as recommended by NIOSH.[7-9] This evacuation flow rate was verified at the beginning of each subject's trials.

Nitrous oxide/oxygen was delivered at a constant flow rate from a portable nitrous oxide machine (MXR, Porter Instrument Co., Hatfield, PA). The total flow rate was adjusted individually for each subject according to the distention of the reservoir breathing bag. Subjects were instructed to breath only through their nose by keeping their mouth closed. They were asked to perform the tests at their highest possible level of concentration and performance. Oxygen (100%) was administered for 5 min at both the beginning and end of the second and third trials. The subjects inhaled 50% nitrous oxide (with or without scavenging) for 5 min before initiation of the second and third trials to ensure sufficient time for onset of sedative effects. The same nitrous oxide unit and adult-sized scavenging mask assembly system (cleaned and sterilized) were used for all subjects.

Ventilation rate for the test room measured 9.4 room air exchanges per hour. The test room was free of auditory and visual distractions. Subjects were encouraged to halt testing if they experienced discomfort, nausea, or dizziness. Subjects were monitored for adverse side effects through direct visual observation and by pulse oximetry (pulse oximeter model #503, Criticare Systems Inc., Milwaukee, WI).

Statistical differences in the subject's performance on the psychomotor and cognitive tests were evaluated using paired Student's *t*-tests. Each subject served as his/her own control. All statistical tests were conducted at the alpha = 0.05 level.

Results

The subject group consisted of 26 males and 4 females ranging in chronologic age from 21 to 45 years

of age. No nitrous oxide complications were observed during the trials and no subjects withdrew their participation in the study.

Table 1 illustrates the effect of scavenging on the subject's speed of finger tapping when inhaling 50% nitrous oxide. There was a statistically significant improvement in the speed of finger tapping during scavenging for all three conditions tested: using the index finger on the dominant hand, nondominant hand, and alternating hands.

Table 2 demonstrates the effect of scavenging on hand/eye coordination. Scavenging did not reduce the errors performed during tracing exercises, which served as a test for hand/eye coordination.

Table 3 illustrates the effect of scavenging on psychomotor coding speed and recall (symbol/digit substitution test). Scavenging significantly improved performance on symbol/digit coding speed and recall accuracy but the improvement in symbol/digit recall speed was not statistically significant.

TABLE 1. EFFECT OF SCAVENGING ON SPEED OF FINGER TAPPING

	Training Trial (100% O_2)	*50% N_2O With Scavenging*	*50% N_2O Without Scavenging*	P-*value**
Dominant hand				
Frequency†	62.1	62.5	59.1	0.0035
(SD)	(10.4)	(8.0)	(8.1)	
Nondominant hand				
Frequency†	57.3	56.4	53.1	0.0007
(SD)	(8.2)	(7.5)	(7.9)	
Alternating hands				
Frequency†	88.1	85.8	82.5	0.0093
(SD)	(14.8)	(14.8)	(15.7)	

* paired Student's *t*-test (alpha = 0.05) to compare N_2O with scavenging to N_2O alone

† mean number of taps recorded in two consecutive 10-second intervals

TABLE 2. EFFECT OF SCAVENGING ON HAND/EYE COORDINATION

	Training Trial (100% O_2)	*50% N_2O With Scavenging*	*50% N_2O Without Scavenging*	P-*value**
Sine Wave Tracing				
rms error†	5.42	4.13	4.56	0.1061
(SD)	(2.52)	(1.48)	(1.96)	
Sawtooth Tracing				
rms error†	6.46	6.57	6.36	0.6716
(SD)	(1.23)	(2.75)	(1.79)	

* paired Student's *t*-test (alpha = 0.05) to compare N_2O with scavenging to N_2O alone

† root mean square error as a unitless measure of vertical deviation from the tracing

TABLE 3. EFFECT OF SCAVENGING ON PSYCHOMOTOR CODING SPEED AND RECALL

	Training Trial (100% O_2)	*50% N_2O With Scavenging*	*50% N_2O Without Scavenging*	P-*value**
Coding Speed				
seconds/symbol	1.43	1.61	1.71	0.0323
(SD)	(0.21)	(0.27)	(0.26)	
Recall Speed				
seconds/correct symbol	2.17	2.12	2.34	0.4319
(SD)	(0.98)	(1.19)	(1.39)	
Recall Accuracy				
frequency correct	6.0	6.0	5.0	0.0211
(SD)	(2.8)	(2.4)	(2.6)	

* Paired Student's *t*-test (alpha = 0.05) to compare N_2O with scavenging to N_2O alone

Discussion

There is ample scientific evidence to support the finding that nitrous oxide at concentrations of 25–50% can inhibit human psychomotor performance.[16–19] This impairment in performance is dose related, predominately identified in performance tasks involving psychomotor speed, and sensitive to detection by the specific computer-administered tests employed in this study.[14, 15] The use of scavenging in this pilot study affected most of the psychomotor and cognitive parameters known to be affected by nitrous oxide in these reported studies.

Results of the present study compared favorably to previously reported trials confirming increased response latency in psychomotor and cognitive performance using the same testing methodology.[14, 15] The computerized neurobehavioral tests most affected by scavenging were finger-tapping speed, symbol/digit coding speed, and symbol/digit recall accuracy. Hand/eye coordination evaluated by pattern tracing, however, was not significantly improved with scavenging and may not be as sensitive to subtle changes in impairment produced by nitrous oxide scavenging.

The order of trials (with and without scavenging) was randomized to control for the effects of practice and to control for any carryover effect between trials.

Stratifying the data based on the order of the trials did not alter the apparent magnitude or direction of the scavenging effect (data not shown). The initial 5-min exposure to nitrous oxide before commencing each trial was deemed appropriate based upon the reported 2- to 5-min delay in onset of peak psychomotor impairment induced by nitrous oxide inhalation.[19,20] The 10-min interval used between each trial was based upon the reported rapid time (5–10 min) course of recovery to control level functioning after inhalation cessation.[19,21]

The scavenger system used in this study was selected because it was the only ADA-approved system at the time. However, no scavenging system is currently accepted by the ADA Council on Dental Materials, Instruments, and Equipment because in May, 1994, the Council voted to rescind the guidelines used in the evaluation of nitrous oxide scavenging systems in the Seal of Acceptance program.[3]

Nitrous oxide scavenging is effective in reducing ambient nitrous oxide levels in the dental operatory[2–4] and is mandated by the ADA.[5,6] NIOSH recommends a 45 L/min scavenging flow rate with a room ventilation rate of 10 room air exchanges per hour to maximize the removal of ambient nitrous oxide levels from the breathing zone of dental personnel.[7–9]

The results of this pilot study suggested that scavenger operation under these conditions may reduce the level of psychosedation obtained by patients. If further study with more subjects confirmed that nitrous oxide scavenging inhibited the level of sedation achieved, then further exploration to test procedural variations in nitrous oxide/oxygen delivery (either increasing nitrous oxide flow rate and/or concentration) to compensate for the impact of scavenging in the dental operatory would be warranted in the future.

Conclusion

This results of this study of 30 healthy human adult subjects supported the following conclusions:

1. Scavenging during nitrous oxide/oxygen inhalation sedation improved performance on several computerized neurobehavioral tests
2. Scavenging at the evacuation rate of 45 L/min as recommended by NIOSH to effectively reduce ambient nitrous oxide could adversely affect the psychosedation level of the dental patient.

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