



# The physiological effects of supplemental oxygen *versus* nitrous oxide/oxygen during conscious sedation of pediatric dental patients

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## Abstract

**Purpose:** This study was performed to compare the effects of nitrous oxide/oxygen ( $N_2O/O_2$ ) versus oxygen ( $O_2$ ) as adjuncts to an oral narcotic regimen for pediatric conscious sedation.

**Methods:** Using a randomized double-blind crossover design, 19 children (mean age  $41 \pm 8.6$  months) were sedated with chloral hydrate (50 mg/kg), meperidine (1.5 mg/kg) and hydroxyzine pamoate (25 mg) for two appointments. Patients were assigned randomly to receive 100%  $O_2$  at one visit and 50%  $N_2O/O_2$  at the other. Physiologic parameters were measured in five-minute intervals, including respiratory rate, pulse rate (PR), oxyhemoglobin saturation ( $SpO_2$ ) and end-tidal carbon dioxide. Data analyses focused on true desaturations and apnea, level of sedation and sedation outcomes.

**Results:** There were no differences in PR,  $SpO_2$  and risk of desaturation between the inhalation agents. The level of sedation was deeper and the sedation outcomes were better in the  $N_2O/O_2$  group.

**Conclusion:**  $N_2O/O_2$  deepened the sedation while improving its success with minimal alteration in physiologic parameters. (*Pediatr Dent* 22:125-133, 2000)

Conscious sedation (CS) is reasonably easy to administer, affordable and carries a relatively low risk of complications.<sup>1</sup> For these reasons, parents often favor this modality over general anesthesia as an alternative for managing young uncooperative children in the dental setting.<sup>1-4</sup> CS is popular for dentists who care for children. Based on a survey of members of the American Academy of Pediatric Dentistry (AAPD) reported by Houpt<sup>5</sup> in 1993, approximately 1,500 respondents performed between 120-140,000 conscious sedations yearly.

## Nitrous Oxide/Oxygen ( $N_2O/O_2$ ) analgesia as an adjunct for CS of pediatric dental patients

$N_2O/O_2$  analgesia has been used for inhalation sedation or relative analgesia in dentistry for many years. It has a wide margin

of safety and can be titrated for the desired level of sedation; accordingly, it is commonly used for anxious children of all ages.<sup>6</sup> A survey of the members of American Board of Pediatric Dentistry by Davis<sup>7</sup> in 1988 reported that 90% of the respondents used  $N_2O/O_2$ , a utilization rate that increased dramatically compared to previous surveys in 1971 (35%) and 1980 (65%).

$N_2O/O_2$  is a popular adjunct for CS in children. On the basis of his detailed surveys of sedation practices among North American pediatric dentists, Houpt<sup>5,8</sup> reported that  $N_2O/O_2$  was used frequently as a comediant with many different drug combinations by both practitioners and training programs in the speciality. In a survey of 25 practitioners who reported using sedation with at least two patients/day, Houpt<sup>9</sup> found that  $N_2O/O_2$  was used for 78% of the sedation visits. The most recent survey of the active members of AAPD by Wilson<sup>10</sup> in 1996 focused specifically on the use of  $N_2O/O_2$  in terms of frequency, armamentarium and monitoring. This study reported that 61% of 1,758 respondents used  $N_2O/O_2$  with other sedative agents. This finding should not be surprising because a substantial majority of the published CS studies in the past decade have included  $N_2O/O_2$  as an integral part of the sedative regimen.<sup>11-20</sup>

## Oxygen ( $O_2$ ) supplementation

The theoretical advantages of  $O_2$  supplementation during CS have been discussed in several investigations.<sup>21-23</sup> It is postulated that supplemental  $O_2$  elevates the arterial oxygen tension ( $PaO_2$ ) to levels estimated as high as 400-600 mg Hg as compared to 100 mg Hg with breathing normal room air.<sup>24</sup> This  $PaO_2$  and the increased  $O_2$  available in the functional residual capacity of the lung provide an  $O_2$  reserve that delays desaturation in the apneic patient. It has been speculated that the use of supplemental  $O_2$  probably produces more dramatic results in children than in adults because of the relatively decreased functional residual lung capacity in children.<sup>25</sup>

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**Table 1. Brodsky's Tonsil Classification System**

0	Tonsils are situated in tonsillar fossa, with impingement on the oropharyngeal airway.
+1	Tonsils sit just outside the tonsillar fossa with obstruction of less than 25% of the airway.
+2	Tonsils are readily seen in the airway and 25-50% of the airway is obstructed.
+3	Tonsils obstruct 50-75% of the airway.
+4	Tonsils obstruct greater than 75% of the airway.

There are clinical findings to support these theoretical beneficial effects of O<sub>2</sub> supplementation in children. Croswell et al.<sup>25</sup> studied the physiologic parameters in 39 patients (ages 24-48 months) sedated with a narcotic drug regimen and 100% O<sub>2</sub> supplementation, reporting no true desaturation episodes. In a well-controlled cross-over design study in preschool children by Rohlfig et al.,<sup>24</sup> the risk of desaturation was lower in those who were given O<sub>2</sub> supplementation. Furthermore, in this study there were no true desaturations following apneic episodes when O<sub>2</sub> was used, while desaturations were not uncommon in the same children when they did not receive supplemental O<sub>2</sub>.<sup>24</sup> The levels of oxyhemoglobin saturation (SpO<sub>2</sub>) values displayed by pulse oximetry were always maintained as high as 99% in the supplementation visits. This study provided strong support that supplemental O<sub>2</sub> provides an extra margin of safety during pediatric CS.<sup>24</sup>

#### N<sub>2</sub>O/O<sub>2</sub> versus O<sub>2</sub>

As noted previously, N<sub>2</sub>O/O<sub>2</sub> analgesia is a popular adjunct to CS for children.<sup>5, 8</sup> There is compelling evidence that the addition of N<sub>2</sub>O/O<sub>2</sub> to the sedation regimen yields improved child patient behavior in the sedation setting.<sup>11-13</sup> This finding was underscored recently by Wilson et al.<sup>18</sup> in a well-controlled clinical trial that found that 50% N<sub>2</sub>O/O<sub>2</sub> improved behavior outcomes for children (mean age 42 months) sedated with chloral hydrate and hydroxyzine.

The use of N<sub>2</sub>O/O<sub>2</sub> analgesia as an adjunct to CS has been theorized as another way to provide supplemental O<sub>2</sub> for a sedated patient.<sup>21,23,26</sup> For example, a child receiving 40% N<sub>2</sub>O/O<sub>2</sub> is, in effect, being supplemented with 60% O<sub>2</sub>, which has the potential to increase SpO<sub>2</sub> to the same levels as 100% O<sub>2</sub>. There is some support for this theory. In a blinded cross-over clinical study examining the addition of 50% N<sub>2</sub>O/O<sub>2</sub> to an oral regimen of chloral hydrate (40 mg/kg) and hydroxyzine (2 mg/kg) in preschool children (mean age 45 months), McCann et al.<sup>13</sup> reported no differences in the patients' respiratory rate (RR), pulse rate (PR) and SpO<sub>2</sub> either with O<sub>2</sub> alone or N<sub>2</sub>O/O<sub>2</sub>. All children maintained excellent SpO<sub>2</sub> values, while those who received N<sub>2</sub>O/O<sub>2</sub> exhibited better cooperative behavior. Similar findings were reported recently by Wilson et al.<sup>18</sup> in a study examining the effects of 50% N<sub>2</sub>O/O<sub>2</sub> versus 100% O<sub>2</sub> in 20 children (mean age 42 months) sedated with 50 mg/kg chloral hydrate and 2 mg/kg hydroxyzine. This study found no differences in physiologic parameters with O<sub>2</sub> versus N<sub>2</sub>O/O<sub>2</sub>; however, N<sub>2</sub>O/O<sub>2</sub> reduced crying and struggling behaviors significantly, without deepening the sedation beyond a desirable level. This finding relative to the behavior of sedated patients underscores why adjunctive N<sub>2</sub>O/O<sub>2</sub> is so popular among practitioners.

Not all data support the concept that N<sub>2</sub>O/O<sub>2</sub> analgesia provides the beneficial physiologic effects that might be anticipated with supplemental O<sub>2</sub> alone. In the most recent survey<sup>10</sup> of AAPD members, a larger percentage of practitioners reported experiences with compromised airways when children were sedated with N<sub>2</sub>O/O<sub>2</sub> combined with other sedatives versus those with N<sub>2</sub>O/O<sub>2</sub> only. This raises the question

of whether adjunctive N<sub>2</sub>O/O<sub>2</sub> can push conscious sedation to deep sedation. Moore et al.<sup>27</sup> (1984) offered such evidence in a well-designed clinical study in which he examined regimens of 20, 40 or 60 mg/kg of chloral hydrate with and without 40% N<sub>2</sub>O/O<sub>2</sub>. At the 60 mg/kg dose with N<sub>2</sub>O/O<sub>2</sub>, Moore reported loss of airway control in some young children. These findings hint that N<sub>2</sub>O/O<sub>2</sub> analgesia may have an additive effect that is not detectable at low to moderate sedative doses of chloral hydrate, but which may be seen at higher doses.

Litman et al.<sup>16</sup> reported evidence that N<sub>2</sub>O/O<sub>2</sub> can deepen the level of sedation in children. He investigated children 1 to 9 years of age sedated with the relatively high dosage of 70 mg/kg chloral hydrate plus N<sub>2</sub>O/O<sub>2</sub> analgesia concentrations of 30% and 50% respectively for 10 minutes prior to general anesthesia. Although there were no significant changes in SpO<sub>2</sub> and RR, this study found that at levels of only 30% N<sub>2</sub>O/O<sub>2</sub>, 94% of the children experienced hypoventilation and were in deep sedation defined as no response to intravenous catheter insertion. Furthermore, all but one child met the criteria for deep sedation at 50% N<sub>2</sub>O/O<sub>2</sub>.

Similar findings were reported in another study by Litman et al.<sup>14</sup> that examined children ages 1-3 years of age who were undergoing elective, ambulatory surgery. These patients were premedicated with 0.5 mg/kg oral midazolam hydrochloride and inhaled N<sub>2</sub>O/O<sub>2</sub> in tritrated concentrations of 15%, 30%, 45% and 60% for four minutes at each concentration. Starting at 30% N<sub>2</sub>O, 60% of the children experienced mild respiratory depression. Sedation levels also began to progress from conscious to deep sedation at 30% N<sub>2</sub>O.

Taken together, Litman's findings offer strong evidence that N<sub>2</sub>O/O<sub>2</sub>, even at levels as low as 30%, has the potential for deep sedation with either a high dosage (70 mg/kg) of chloral hydrate or a moderate dosage (0.5 mg/kg) of midazolam. However, interpretation of Litman's findings are not directly applicable to the dental setting where children are often stimulated constantly by oral manipulation and the noise of the dental handpiece.

In summary, current scientific evidence offers conflicting explanations relative to the role of N<sub>2</sub>O/O<sub>2</sub> as an adjunct in CS. Moreover, to date no investigations have examined the use of a narcotic sedative regimen with O<sub>2</sub> versus N<sub>2</sub>O/O<sub>2</sub> in the dental environment. Accordingly, the purpose of this study is to examine the safety of the popular drug regimen of 1.5 mg/kg meperidine, 50 mg/kg chloral hydrate and 25 mg hydroxyzine pamoate either with 50% N<sub>2</sub>O/O<sub>2</sub> versus 100% O<sub>2</sub> for preschool children requiring CS for dental procedures.

#### Methods

The study was approved by the Committee on Investigations Involving Human Subjects at the University of North Caro-

**Table 2. Scoring the Level of Sedation**

Score	Responsiveness	Clinical Response
0	Not sedated	Uncooperative, resists monitor or face mask placement, crying, screaming
1	Uninterrupted interactive ability (anxiolysis)	Totally awake; verbalizes spontaneously
2	Minimally depressed level of consciousness (Interactive)	Eyes open or temporarily closed; responds appropriately to verbal commands
3	Moderately depressed level of consciousness (Non-interactive; arousable with mild to moderate stimuli)	Mimics physiologic sleep, eyes closed most of the time; may or may not respond to verbal prompts alone; responds to mild/moderate stimuli* appropriately (reflex withdrawal and verbalization; complaint, moan, crying); airway only occasionally may require readjustment via chin thrust
4	Deeply depressed level of consciousness (Non-interactive; arousable with intense, repeated stimuli)	Eyes closed; does not respond to verbal prompts alone; responds to intense stimuli** with reflex withdrawal with no verbalization; airway requires frequent management

\* Repeated trapezius pinching or needle insertion in oral tissue.

\*\* Repeated, prolonged and intense pinching of the trapezius.

lina at Chapel Hill. All sedations were performed in the Pediatric Sedation Clinic (PSC) at UNC-CH. The sample consisted of pre-school aged patients who required conscious sedation for dental treatment because of behavior management difficulties with conventional care. All children (1) needed at least two dental visits under local anesthesia (2) were classified as Class I by American Society of Anesthesia (ASA) anesthesia risk classification and (3) had a tonsil size falling within 0-3 of the Brodsky's<sup>28</sup> classification scale (Table 1).

The study was conducted in strict compliance with a standard of care established by AAPD.<sup>29</sup> A pre-sedation physical examination was completed by the child's physician for each child participant. Parents were informed fully of the study and written consent was obtained for their children to participate in the investigation. Written pre- and post-operative instructions were given for each appointment for each child.

### Study design

A randomized double-blind cross-over design was used so that each child served as his/her own control. Each patient was assigned randomly to receive either O<sub>2</sub> supplementation or 50% N<sub>2</sub>O/O<sub>2</sub> analgesia for the first visit with the alternate inhalation agent administered during the second visit. A secondary investigator (SI) made all random assignments and administered the inhalation agents in such a manner that principal investigator (PI) and the dental operator were blinded to the inhalation assignment at each appointment.

### Procedures

The patients were weighed and baseline SpO<sub>2</sub> and PR were obtained immediately prior to administration of their oral medications using the BCI International 9000 Capnograph/Oximeter Monitor<sup>®</sup> (BCI International, Waukesha, WI). All patients were given an oral regimen of 50 mg/kg chloral hydrate (Pharmaceutical Basics, Inc., Morton Grove, IL), 25mg hydroxyzine pamoate (Vistaril<sup>®</sup>, Pfizer Laboratories, New York,

NY), and 1.5 mg/kg meperidine (Demerol<sup>®</sup>, Winthrop-Breon, New York, NY). After the administration of sedation medicine, the children waited with their parent(s) in a quiet dimly lighted holding area. Approximately 45 minutes after oral drug administration, all patients were transferred to the dental operatory, placed in a Papoose Board<sup>™</sup> (Olympic Medical Group, Seattle, WA) and all monitors were attached.

The treatment was planned for each patient so that each of the two visits would be comparable in terms of difficulty and minimum appointment length. However, when patients were well sedated and cooperative operators always attempted to complete as much work as possible. The maximum dosage of local anesthetic agent for each patient was calculated on the basis of a maximum of 4.4 mg/kg prior to each appointment. Two percent lidocaine hydrochloride with 1:100000 epinephrine (Xylocaine<sup>™</sup>) was used in the study. In some instances, the amount of treatment was limited by the amount of anesthesia that could be administered.

### Inhalation agents: N<sub>2</sub>O/O<sub>2</sub> versus O<sub>2</sub>

Inhalation agents were delivered via nitrous delivery unit and a scavenging nasal mask (Mission/Mizzy Comfort cushion analgesia circuit and scavenging kit, Mission Dental Inc., NJ) placed over the patient's nose. To blind the PI from the inhalation agent used, the nitrous delivery unit was covered with a hood at all times and all inhalation agents were manipulated by the SI.

For the N<sub>2</sub>O/O<sub>2</sub> appointments, patients breathed 100% O<sub>2</sub> at a three liter per minute flow rate for the first five minutes, then 50% N<sub>2</sub>O/O<sub>2</sub> at a three liter per minute flow rate was administered throughout the remainder of the appointment. At the conclusion of the appointment, 100% O<sub>2</sub> was administered for five minutes prior to the patients' dismissal. For the 100% O<sub>2</sub> appointments, a flow rate of three liters per minute was administered all through the procedure. To insure that the PI was blinded to the inhalation agent used, the SI simulated the same

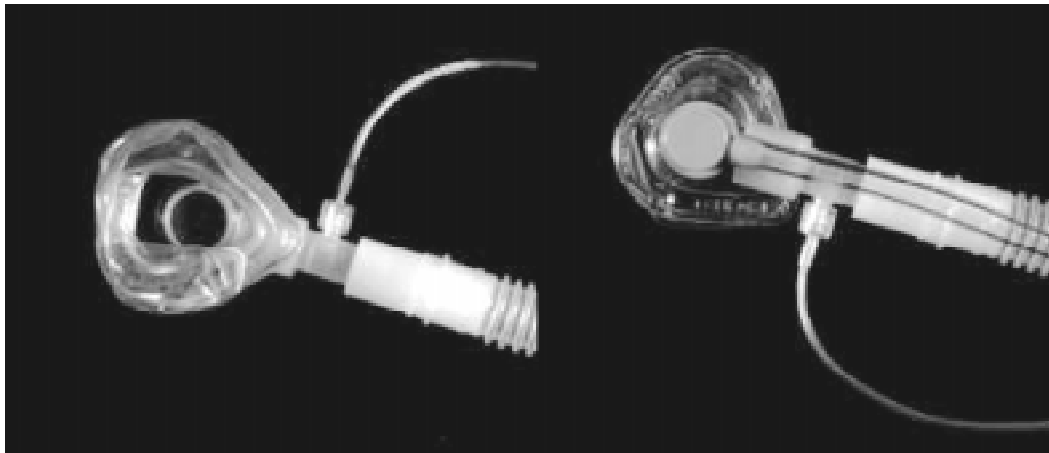


Fig 1. Nasal mask with CO<sub>2</sub> sampling port. The port attaches into the straight connector which joins the nasal mask to the fresh gas flow. Noted that CO<sub>2</sub> sampling port located between fresh gas flow and the scavenging exhalation valve.

inhalation routines including scavenging system utilization for all appointments.

### Physiologic monitoring and data collection

Patients were monitored continuously throughout the appointments. A precordial stethoscope was used to monitor heart and breathe sounds. A BCI International 9000 Monitor<sup>®</sup> (BCI International, Waukesha, WI), a combination pulse oximeter-capnometer, was used for physiologic parameters. The pulse oximeter probe was attached to the great toe of left foot. The foot was covered with a towel to reduce ambient light. Expired carbon dioxide was collected via a sampling tube connected from the nasal mask to the capnograph (Figure 1). Physiologic data including PR, RR, SpO<sub>2</sub> and end-tidal carbon dioxide tension (ETCO<sub>2</sub>) were recorded manually by PI in five-minute intervals using a time-based anesthesia record. A hard copy containing continuous data of these parameters was printed out for each patient at the end of each appointment using the capnometer's Seiko STP-411 internal printer.

Blood pressure was not monitored in this study because the goal of the study was conscious sedation and thus the monitoring was focused on respiratory monitoring. Furthermore, the blood pressure cuff can be counter-productive during conscious sedation because it can disturb or agitate the sedated child.

True desaturation was defined as a drop in SpO<sub>2</sub> of 5% from baseline in a patient who was immobile and quiet. True apnea was defined as capnograph reading of zero for RR and ETCO<sub>2</sub> and/or no visual signs of breathing and no breath sounds au-

dible via the precordial stethoscope for longer than 25 seconds.<sup>22</sup>

The PI recorded levels of sedation using a scale modified from AAPD *Guidelines for Elective Use of Pharmacologic Conscious Sedation and Deep Sedation in Pediatric Dental Patients* 1996<sup>29</sup> (Table 2). The levels were recorded during the treatment procedures including mouth prop insertion, topical anesthetic agent application, local anesthetic injection, rubber dam clamp placement and tooth preparation with dental bur and then in the same interval as physiologic data. By consensus agreement, the dental operator and PI assessed the overall sedation outcome at the conclusion of the appointment using a subjective scale described in Table 3.

### Data analysis

Data were analyzed using SAS Program Version 6. Wilcoxon's Rank Sum tests were used to determine the sequence and period effects of the random assignment of O<sub>2</sub> versus N<sub>2</sub>O. Student *t*-tests and Wilcoxon Matched-Paired Signed-Rank tests were used to compare age, weight, baseline physiological factors and descriptive data between two groups of children. Wilcoxon Matched-Paired Signed-Rank tests were used also to test the differences in medians for PR, RR, SpO<sub>2</sub>, ETCO<sub>2</sub> and level of sedation for N<sub>2</sub>O/O<sub>2</sub> versus O<sub>2</sub> supplementation. The Cochran-Mantel-Haenszel statistic was utilized to determine the association between the levels of sedation and the dental procedures for each group.

The differences between the occurrence of desaturation and apnea for O<sub>2</sub> versus N<sub>2</sub>O/O<sub>2</sub> were tested using McNemar test for matched paired data. A Fisher's exact test was used to determine if there was an effect of tonsil size on desaturation and apnea episodes in the two test groups. Wilcoxon Matched-Paired Signed-Rank tests were used to compare the frequency of desaturation and apnea episodes between O<sub>2</sub> and N<sub>2</sub>O/O<sub>2</sub> groups. To assess the association between SpO<sub>2</sub>, PR, RR, the level of sedation and local anesthesia dosage and desaturation occurrence, median differences were

Table 3. Sedation Outcome Assessments\*

0	<b>Excellent</b>	Treatment completed without difficulty, minimal crying and patient quiet and/or asleep for most of case
1	<b>Satisfactory</b>	Treatment completed with minimal difficulty, but alternating periods of crying and struggling with period of quiet and/or sleep
2	<b>Unsatisfactory</b>	Treatment completed with difficulty due to crying and struggling throughout treatment
3	<b>Aborted</b>	Treatment not completed due to combative behavior that increased the risk of injury to the patient or dental team

\* Modified from Croswell et al.<sup>25</sup>, 1995.

Table 4. Descriptive Data

		O <sub>2</sub> supplementation	N <sub>2</sub> O/O <sub>2</sub> analgesia	P value
Baseline SpO <sub>2</sub> in %	mean±SD	98 ± 0.3	98 ± 0.2	0.842
	Range	95 - 100	97 - 100	
Baseline PR per minutes	mean±SD	106 ± 2.7	104 ± 2.6	0.760
	Range	85 - 130	80 - 124	
Waiting time in minutes	mean ±SD	53 ± 9.0	58 ± 10.1	0.193
	Range	35 - 70	40 - 75	
Tonsil size in Brodsky's scale	mean±SD	1.8 ± 0.2	1.8 ± 0.2	0.566
	Range	0 - 3	0 - 3	
Local anesthesia in mg	mean±SD	47 ± 10.5	58 ± 9.1	0.007*
	Range	36.0 - 64.0	36.0 - 72.0	
Treatment time in min	mean±SD	66 ± 24.2	65 ± 21.0	0.604
	Range	35 - 130	30 - 120	

\* Statistically significant P<0.05.

tested using Mann-Whitney U tests for the O<sub>2</sub> and N<sub>2</sub>O groups. Partial correlation was employed to test the association between average local anesthesia dosage and frequency of desaturation in both groups. Finally, a McNemar test was used to determine whether different inhalation supplementation resulted in significantly different sedation outcomes. An alpha of 0.05 was used as the level of significance for all of these tests.

## Results

Parental consent was requested for 24 children to participate in the study. Consent was denied by one of two parents for one child. A second child failed to meet the criteria for tonsil size and was not enrolled; thus, 22 children went forward in the study. Three cases were aborted at the initial sedation appointment and referred for treatment under general anesthesia.

Nineteen children completed the study, including 13 boys and six girls with mean age of 41 months (range 26-55 months). The mean weight of the children was 16 kg (range

13-24 kg). Tonsil size ranged from Brodsky's scale 0-3 with most children having a tonsil size of 2. The randomized assignment of visits resulted in nine patients receiving O<sub>2</sub> supplementation at the first appointment and 10 receiving N<sub>2</sub>O/O<sub>2</sub> at the first appointment.

There were no statistical differences in the age and weight of the two study groups (*t*-test, *P*=0.59 and 0.39 respectively). The physiologic baselines and descriptive data of the study are illustrated in Table 4. There were no statistically significant differences in these data between two test groups (Wilcoxon Matched-Paired Signed-Rank tests, *P*>0.1) except for the average dosage of local anesthesia (paired *t*-test, *P*=0.0073). Finally, the Wilcoxon Rank Sum test revealed no sequence and period effects on PR, RR, SpO<sub>2</sub> and level of sedation.

## Physiologic data

The physiologic parameters of PR, RR and SpO<sub>2</sub> are illustrated in Table 5. The differences in PR and SpO<sub>2</sub> between different visits were not statistically significant, while the difference

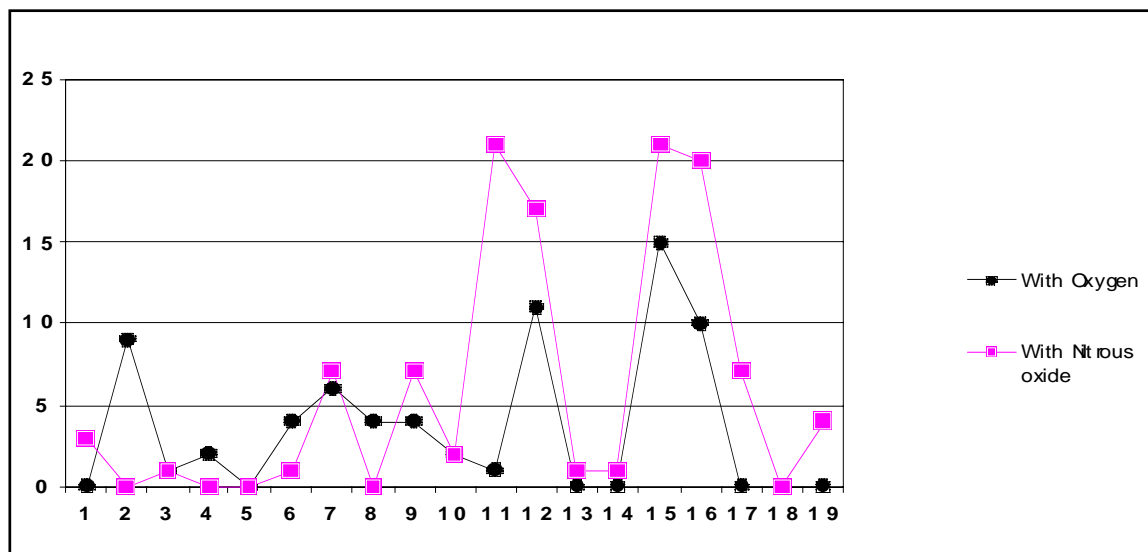


Fig 2. Desaturation events in each patient.

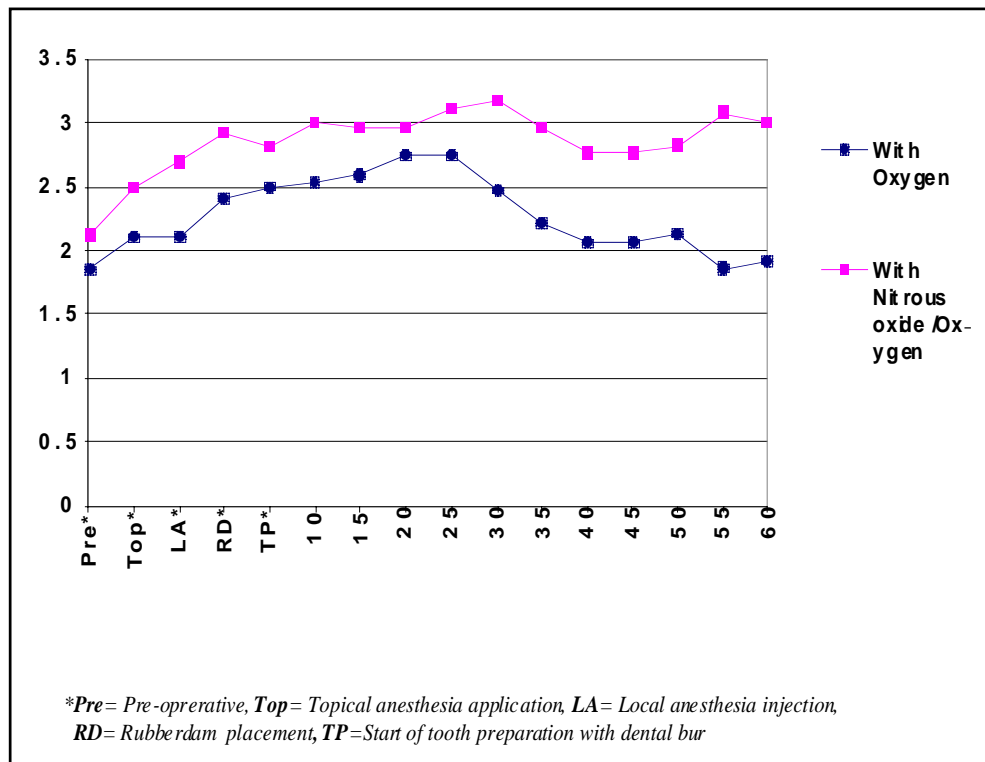


Fig. 3 Level of sedation.

in RR was marginally significant (Wilcoxon Matched-Paired Signed-Rank test,  $P=0.045$ ).

#### Desaturation and apnea

Using the precordial stethoscope and/or capnograph, no true apneic events were detected in any child at any time during the study. Desaturation events occurred in both  $O_2$  and  $N_2O/O_2$  supplementation visits. Desaturation occurred in more  $N_2O/O_2$  visits (14/19) than  $O_2$  visits (12/19); this difference was not statistically significant (McNemar tests,  $P=0.70$ ). Figure 2 (or Table 6) illustrates desaturation events for each patient throughout the study period. The frequency of desaturation was higher for  $N_2O/O_2$  visits; the number of mean desaturation events was 5.9 in the  $N_2O/O_2$  group versus 3.6 in the  $O_2$  group, but this difference was not statistically significant (Wilcoxon Matched-Paired Signed-Rank,  $P=0.26$ ).

Because the local anesthesia dosages were different between the two study groups, the association of local anesthesia and the frequency of desaturation was analyzed. This association was not statistically significant (partial correlation,  $P=0.915$ ).

Neither tonsil size, PR, RR nor  $SpO_2$  influenced the risk of desaturation. The effect of level of sedation on desaturation was not statistically significant in any time point except at the maximum level of sedation, a point at which the risk of desaturation increased significantly (Mann-Whitney U test,  $P=0.042$ ).

#### Level of sedation

The overall level of sedation was  $2.2 \pm 0.6$  when patients were supplemented with  $O_2$  versus  $2.9 \pm 0.8$  when supplemented with  $N_2O/O_2$ . Figure 3 illustrates that differences in the level of sedation were statistically significant at all time points (Wilcoxon Matched-Pair Signed-Rank test,  $P$  values ranged from 0.0016-0.04). There was a significant association between

the level of sedation and the dental procedures including topical anesthesia application, local anesthetic injection, rubber dam clamp placement and tooth preparation (Cochran-Mantel-Haenszel Statistics,  $P=0.001$ ).

#### Sedation outcomes

At the conclusion of each appointment the sedation outcome was rated by consensus of the dental operator and sedation monitoring assistant. The results for  $O_2$  supplementation visits were excellent 42%, satisfactory 37% and unsatisfactory 21% respectively. For  $N_2O/O_2$  supplementation visits the results were 69%, 26% and 5% respectively. Eight children had the same sedation outcomes at both visits (six excellent and two satisfactory), nine had better outcomes with  $N_2O/O_2$  and two had better outcomes with  $O_2$ . This difference was significant (McNemar test,  $P=0.035$ ).

#### Discussion

The major goal of this study was to evaluate the safety of a narcotic sedation regimen when used in conjunction with 100%  $O_2$  supplementation versus  $N_2O/O_2$  analgesia. The double-blind crossover research design was appropriate to compare and assess the effects of the two inhalation agents on physiologic parameters, the level of sedation and adverse events. Our descriptive results (Table 3) revealed no differences between the  $N_2O/O_2$  versus  $O_2$  groups for baseline  $SpO_2$ , PR, waiting time prior to dental treatment, tonsil size and total treatment time. These findings confirmed our random assignment.

There was a significant difference in the amount of local anesthesia administered, with the  $O_2$  group receiving an average of 47.2 mg of 2% lidocaine with 1:100000 epinephrine versus 57.7 mg for the  $N_2O/O_2$  group. As illustrated in Figure

**Table 5. Physiologic Parameters**

Parameters	O <sub>2</sub> Supplementation	N <sub>2</sub> O/O <sub>2</sub>	P-value
Pulse rate	126±24.2	121±19.8	0.154
Respiratory rate	20±4.7	21±4.7	0.045*
SpO <sub>2</sub>	97±1.0	97±1.0	0.258

\* Statistically significant  $P < 0.05$ .

3, the N<sub>2</sub>O/O<sub>2</sub> group was more sedated at each procedural point throughout the appointment, a difference that was statistically significant at all time points. It is possible that subjects receiving N<sub>2</sub>O/O<sub>2</sub> received more local anesthesia because they were better sedated prior to and during the administration of local anesthesia and the operators took advantage of this by giving more anesthesia and planning more treatment within the appointment times. This speculation was confirmed by retrospective review of individual sedation appointment records.

**Effect of inhalation agents on physiologic parameters**

At the time this study was undertaken there were no commercially available nitrous oxide nasal masks that included a port for the sampling of expired CO<sub>2</sub>. Although such a system (Figure 1) was designed for this study, over time this system proved to be inconsistent for sampling expired CO<sub>2</sub> via the capnograph. This problem is explained by the fact that some children would occasionally breath primarily through the mouth. At the same time, it is possible that the port of CO<sub>2</sub> sampling port was too far from the patients' nares or the scavenging system may have had an effect on measured expired CO<sub>2</sub> levels. In any event, the actual ETCO<sub>2</sub> values were excluded and not analyzed because of their inconsistency. For future studies the CO<sub>2</sub> sampling port should be placed as close to the patients' nares as possible and the port should also be proximal to the scavenging valve.

There were no differences in the effects of inhalation agents on PR and SpO<sub>2</sub> at any time during the study. SpO<sub>2</sub> hovered consistently at 97% throughout the sedation visits in both groups (Figure 4). Rohlfiing et al.<sup>24</sup> studied children sedated with the same oral regimen used in this study, reporting SpO<sub>2</sub> levels near 100% at all times using a nasal canula delivering 100% O<sub>2</sub>. In comparing these findings to those, we speculate that our nasal mask did not deliver O<sub>2</sub> as effectively as did the nasal canula in Rohlfiing's study, possibly because of inconsistent mask fit with patient's head movements.

The differences in SpO<sub>2</sub> levels between O<sub>2</sub> versus N<sub>2</sub>O/O<sub>2</sub> visits over time are illustrated in Figure 4. These equivocal findings are not surprising; however, at almost all time points, SpO<sub>2</sub> levels at the N<sub>2</sub>O/O<sub>2</sub> visits were lower than at O<sub>2</sub> visit. This finding suggests a trend for 100% O<sub>2</sub> to elevate SpO<sub>2</sub> higher than 50% O<sub>2</sub> at the same flow rate, but this difference was not statistically significant.

Litman et al.<sup>15</sup> reported findings obtained during the induction phase prior to general anesthesia using respiratory inductive plethysmography (RIP) to monitor changes in respiratory pattern of the children, mean age 3.8 years. Litman found that 40% N<sub>2</sub>O as an adjunct to oral midazolam did not depress respiration or lead to airway obstruction. In another study Litman et al.<sup>16</sup> investigated children sedated with 70 mg/kg chloral hydrate and reported that the addition of 30% or 50% N<sub>2</sub>O/O<sub>2</sub> inhalation to chloral hydrate increased the risk of hypoventilation (ETCO<sub>2</sub> >45 mm Hg) significantly.

In this study the respiratory rate was lower when the patients were supplemented with O<sub>2</sub> (Table 5), a finding that corroborates that of Rohlfiing's study (20/min without O<sub>2</sub> supplementation versus 18/min with O<sub>2</sub>).<sup>24</sup> One might expect that the children in the N<sub>2</sub>O/O<sub>2</sub> group were more deeply sedated and would have respiratory depression resulting in decreased respiratory rate but that was not found that in this study. We have no explanation for this finding. Although not likely, it is possible that N<sub>2</sub>O/O<sub>2</sub> acted as a respiratory stimu-

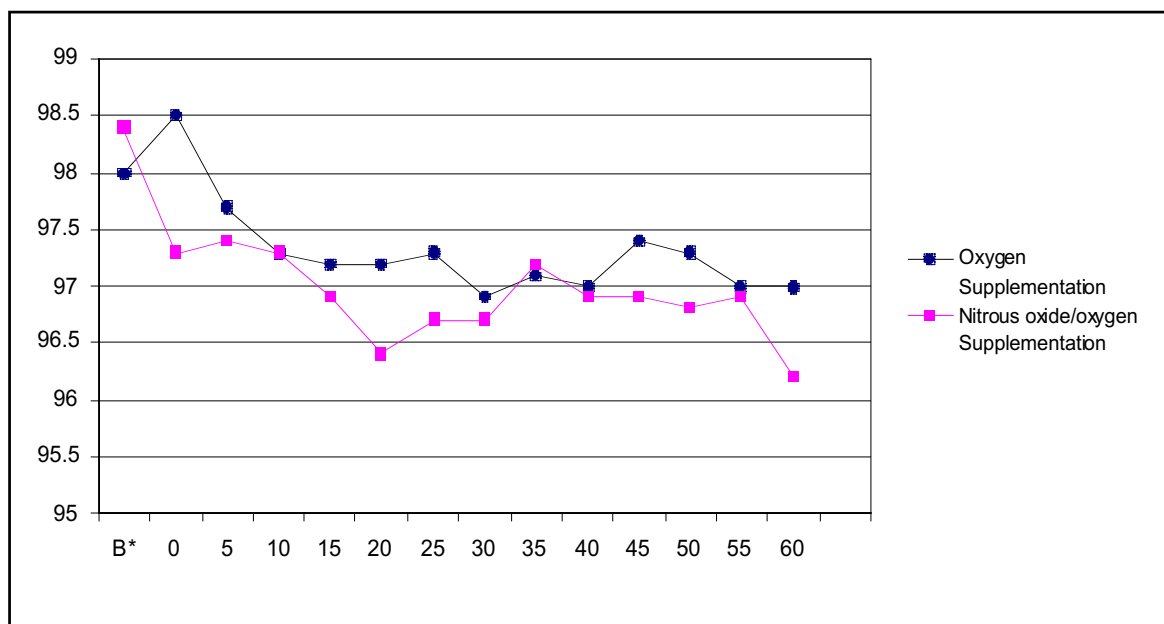


Fig. 4 SpO<sub>2</sub> level during the procedure.

**Table 6. Number of Desaturation Events in Each Patient**

Patient No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
With O <sub>2</sub>	0	9	1	2	0	4	6	4	4	2	1	11	0	0	15	10	0	0	0
With N <sub>2</sub> O/O <sub>2</sub>	3	0	1	0	0	1	7	0	7	2	21	17	1	1	21	20	7	0	4

lant by increasing sympathetic tone. In any event, a difference in RR of 20.1 *versus* 21.4 in this study had no clinical significance.

**Desaturation and apnea**

Respiratory compromise as evidenced by apnea and desaturation episodes was of major interest. Published studies suggest that desaturations are not uncommon in pediatric conscious sedation.<sup>24,31-33</sup> Several factors in the dental environment have been suggested to influence desaturation events in sedated children. These include head and neck position during dental treatment, especially for procedures in mandibular quadrants.<sup>27</sup> The tongue has also been mentioned frequently as a factor in airway obstruction in sedated children.<sup>24,27</sup> Verwest et al.<sup>32</sup> analyzed patients' age, tonsil size and amount of lidocaine patient received, reporting that increased tonsil size and lidocaine dose ( $\geq 1.5$  mg/kg) was related to an increased desaturation during N<sub>2</sub>O/O<sub>2</sub> analgesia in children older than 7 years of age. Another recent study reported that sedated children with large tonsils (Brodsky's scale 3) had compromised ability to maintain the airway independently.<sup>34</sup> In this study tonsil size of 0-3 on the Brodsky's scale<sup>24</sup> did not affect the risk of desaturation and this finding is attributed to the fact that children with tonsillar hypertrophy were excluded. No association was found between lidocaine dose and the frequency of desaturation.

In summary, our results revealed no difference in the desaturation risk of O<sub>2</sub> *versus* N<sub>2</sub>O/O<sub>2</sub>, but the frequency of desaturation was higher with N<sub>2</sub>O/O<sub>2</sub> and the N<sub>2</sub>O/O<sub>2</sub> patients required more airway repositioning after desaturation episodes.

**Level of sedation**

N<sub>2</sub>O/O<sub>2</sub> analgesia improved the success rate of conscious sedation with this oral narcotic regimen. This infers that deeper levels of sedation are obtained with N<sub>2</sub>O/O<sub>2</sub> analgesia, a finding that corroborates many published sedation studies over the past decade.<sup>11-13,18</sup> A recent study by Wilson et al.<sup>18</sup> concluded that 50% N<sub>2</sub>O/O<sub>2</sub> deepened the level of sedation in children sedated with chloral hydrate (50 mg/kg) and hydroxyzine (2mg/kg). In this study children exhibited a deeper level of sedation when they were supplemented with N<sub>2</sub>O/O<sub>2</sub> analgesia *versus* O<sub>2</sub> supplementation (Figure 3). This effect of N<sub>2</sub>O/O<sub>2</sub> on the level of sedation was demonstrated also by Litman et al.<sup>14-16</sup> in a series of investigations that demonstrated deep sedation can be rendered for children with 30-70% N<sub>2</sub>O/O<sub>2</sub> inhalation and oral sedative agents. While the criteria were subjective and imprecise and the attempt to detect "Deep Sedation" was limited to those assessed by intense stimuli, many more patients in this study experienced "level 4 sedation" with N<sub>2</sub>O/O<sub>2</sub> than with O<sub>2</sub>. Considering the fact that children may respond variably to different sedative agents, practitioners must be aware of the possibility that a deeper level of consciousness can be expected with adjunctive N<sub>2</sub>O/O<sub>2</sub>. These results also

showed that deeper sedation was associated with an increased risk of desaturation.

**Conclusions**

- 1) Although there were no differences in the physiologic parameters for pulse rate, or oxyhemoglobin saturation, there was a small increase in respiratory rate in the N<sub>2</sub>O/O<sub>2</sub> group.
- 2) N<sub>2</sub>O/O<sub>2</sub> did not increase risk of desaturation but did increase the frequency of desaturation events.
- 3) N<sub>2</sub>O/O<sub>2</sub> deepened the level of sedation with this narcotic sedation regimen.
- 4) N<sub>2</sub>O/O<sub>2</sub> improved sedation outcomes in patients sedated with this narcotic sedation regimen.
- 5) When N<sub>2</sub>O/O<sub>2</sub> is used with this narcotic sedation regimen, child patients should be monitored with heightened vigilance and monitoring with capnography is recommended.

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## ABSTRACT OF THE SCIENTIFIC LITERATURE



### THE RELATIONSHIP BETWEEN PLAQUE pH AND GLYCEMIC INDEX OF VARIOUS BREADS

Plaque pH was evaluated after 10 subjects ate various types of breads. The pH response was then compared to the glycemic index (GI) as calculated from the incremental blood glucose. pH drops in all the breads were, at first, considerably smaller than that for a sucrose solution control, yet from 30 minutes and onward the breads registered similar or even lower pH than sucrose. A high correlation between plaque pH and GI also was found, i.e. the more the pH dropped in plaque, the higher the GI in blood. The conclusion: from a metabolic and cariogenic point of view, breads with a low GI should be recommended to patients.

**Comments:** While the practical, read clinical, upshot of these findings is somewhat arcane, this study offers yet more evidence that the old "good" and "bad" foods paradigm as it relates to caries prevention is useless. It also helps establish the logic to a systemic model for oral health care. Bread is a staple of any diet in every culture and it appears from this study that it can be just as "cariogenic" as sucrose. This is more weight in favor of dispensing with dietary advice and concentrating in-office education on daily fluoride use and proper home oral hygiene. *SJM*

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