Current Status of Nitrous Oxide as a Behavior Management Practice Routine in Pediatric Dentistry

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ABSTRACT

Nitrous oxide (N_2O) as a behavioral management intervention in children has attained an excellent safety record and is, therefore, used widely. As is true of any diagnostic or therapeutic dental intervention, however, its usage merits periodic review, even if–or particularly when–it is routinely applied. For example, when N_2O is used in combination with other sedatives, such polypharmacy can produce potentially serious side effects. There are also bioenvironmental risks to patients and staff if ambient air is not properly monitored. Using historical publications, current empirical articles, professional usage policies, and educational textbooks, the purpose of this article was to review indications and contraindications of N_2O and discuss various factors that should or should not be considered about its use in the United States. Even though today's parents may be more accepting of pharmacologic approaches such as N_2O, the choice to use it should always be made with the child's best interest in mind.

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Nitrous oxide (**N_2O**) has been available since the mid 1800s, but only gained general acceptance as a dental inhalation sedation in the second half of the 20th century. Its use accelerated in the 1970s and 1980s, leveled off for a brief period because of environmental concerns, and then continued to increase into the 21st century. Today, nitrous oxide usage is a common practice in many general and pediatric dental offices, such that its use has often become routine within the United States. As is true of any diagnostic or therapeutic dental intervention, however, its usage merits periodic review, even if–or particularly when–it is routinely applied.

The purposes of this article are to: review the indications and contraindications of nitrous oxide in the management of children in US dental offices, including risks caused by polypharmacy and problems arising from bioenvironmental exposure in the dental office; discuss usage trends, changes in parenting styles that impact patient management decisions, and N_2O in dental education; and offer 5 summary observations that should be considered when making treatment decisions.

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N_2O BASICS REVISITED

NATURE OF N_2O

N_2O is a slightly sweet-smelling, colorless gas that is administered via inhalation and produces nonspecific central nervous system (**CNS**) depression sufficient to produce modest analgesia.[1] When administered in concentrations between 20% and 50% (and accompanied by 80-50% O_2, respectively), depending on the patient's response, the patient remains awake but calm and able to follow verbal instructions. At extended concentrations above 50% and depending upon the clinical situation, patients may experience unconsciousness and suffer anoxia.

N_2O and similar sedative agents can be classified by the methods of administration, including: inhalation;

orally; or intravenously. They also can be classified by their impact on patients' consciousness, ranging from conscious with control of protective reflexes to general anesthesia with total loss of reflexes. Using these 2 axes, N_2O qualifies as conscious inhalation sedation. The 2007 Guidelines for the Use of Sedation and General Anesthesia by Dentists, issued by the American Dental Association (**ADA**), however, recommend a more specific classification by replacing the single category of conscious sedation as minimal, moderate, or deep sedation.[2]

INDICATIONS AND ADVANTAGES

N_2O is generally indicated for the mild to moderately apprehensive pediatric patient who is able to understand and follow simple instructions. Success outside these parameters may be possible, but more variable. It is particularly useful for the first-time patient who anticipates pain and/or discomfort before dental care has even been initiated. N_2O additionally allows for increased chairside working time for the clinician (particularly significant for dental students) and those patients who tire quickly or experience patient "burn out" when the complexity of the condition or therapeutic plan requires multiple dental visits.

Dentally, N_2O presents a high success rate with rapid onset of action and rapid recovery. The depth and duration of the sedation is readily titrated. It exhibits a superior safety profile with no recorded fatalities or cases of serious morbidity when used alone and in appropriate concentrations for sedation.[3-5] Side effects are minor, limited to headache, nausea and/or vomiting. These effects can be minimized by monitoring the pro-cedure's length, speed of induction, fluctuation of concentration, and reversal of sedation.[1]

In medicine, N_2O has long been used as an inhalation anesthetic for both the induction and maintenance of general anesthesia. More recently, N_2O protocols have been established for pediatric patients undergoing diagnostic procedures such as computer tomography, endoscopy, electroencephalography and bone marrow biopsies.[6]

CONTRAINDICATIONS AND DISADVANTAGES

N_2O is not indicated for every anxious or apprehensive pediatric patient. Its use becomes limited for those patients who resist mask placement and breathing through the mask due to age, maturity level, or mental, behavioral, and personality disorders. It may be ineffective for patients experiencing severe pain. Similarly, if patients suffer from an upper respiratory tract infection, chronic obstructive pulmonary disease, or gas-filled space conditions like acute otitis media, N_2O administration may be contraindicated.[1,7] Fluctuations in concentration or extended exposure may subsequently increase the risk of nausea and/or vomiting. Regardless of the situation or circumstances, whenever it becomes difficult for the clinician to judge the N_2O sedation level, the effectiveness of sedation may become compromised.

Current research is focusing on high and repeated exposure to N_2O during major surgery, especially its impact on the developing infant brain.[8] Reports of increased postoperative homocysteine levels attributed to N_2O anesthesia can lead to postoperative endothelial dysfunction, myocardial ischemia, and infarction.[9] Some authors, therefore, "question the routine use of N_2O in contemporary practice," although it should be emphasized that these concerns focus, at least presently, on N_2O anesthesia for major surgery.[8]

CO–MEDICATION RISKS

N_2O enjoys an undisputed safety record in children when used alone at subanesthetic concentrations. Recognized for its weak potency but effectiveness by both practitioners and liability carriers alike, its widespread use mimics that of local anesthetics.[10] Both have similarly been given a wide level of acceptance and are used routinely and safely when correctly prescribed for a child's smaller body mass and tidal volume.

Additional risks are posed by the combination of N_2O with other sedative drugs given by a different route. Their actions become synergistic, and the potential for CNS depression is magnified, resulting in deeper sedation than desired or anticipated. In such cases, N_2O as a "relative" anesthetic (ie, a drug with effects directly related to the concentration), becomes a misnomer.[11] Furthermore, when N_2O is used alone, laryngeal reflexes remain intact, and patients retain their ability to protect their airway. However, with co-medications, reflexes may become compromised and patients risk aspiration in the event of vomiting, particularly if preoperative fasting was recommended but not observed. Such polypharmacy, including the combination of N_2O with local anesthetics that reach high serum levels, may even lead to respiratory arrest.[12]

BIOENVIRONMENTAL PROBLEMS OF N_2O

N_2O is emitted naturally by bacteria in soils and oceans. It is produced by humans through the burning of fossil fuels and forests and the agricultural practices of soil cultivation and nitrogen fertilization. It also can be used as an oxidizer in rocket motors and in internal combustion engines. N_2O is perhaps best known–or at least most often encountered–as the propellant in ready-use whipped cream and other such food-containing spray cans and as the gas with which snack food packages are filled to prevent the growth of oxygen-dependent bacteria. Altogether, N_2O contributes about 5% to the greenhouse effect. Only a fraction thereof (0.35-2%), however, is actually the result of combined medical and dental applications of N_2O gas.[13]

Hence, more urgent than its impact on our climate is the impact N_2O pollution may have in the dental office itself. N_2O is minimally metabolized when used as

inhalation sedative and excreted primarily through the lungs at a rate similar to its absorption. It retains its potency when exhaled by the patient into the room. This has led to concerns about occupational health hazards for clinic staff, particularly in poorly ventilated areas. Long-term exposure may additionally cause bone marrow suppression and reproductive system disturbances.[14-18] The use of the rubber dam, scavenging equipment, and environmental monitoring, however, have significantly reduced these occupational risks. Inappropriate recreational use of N_2O in and out of the office setting collectively adds to total concentration of gas inhaled. Anesthesiologists acknowledge collateral interest by dentists who are concerned about theater pollution by N_2O and its adverse effects on their patients and staff.[19,20]

Most dental practitioners, however, appear to be unconcerned about the amount of N_2O dispelled within their dental offices. A 1996 survey by Wilson of members of the American Academy of Pediatric Dentistry (**AAPD**) showed that 70% of pediatric dentists never tested ambient levels in their offices.[21] A similar ADA study in 1994 reported that 18% and 29% of dentists who administered N_2O to 10% or more and 10% or less of their patients, respectively, did not use scavenger systems.[22] The intention of testing is to detect equipment failure and assess ambient exposure to patients and staff, regardless of the number of patients who are given N_20.[23]

INCREASE IN N_2O USAGE

DISCOVERY

N_2O was first synthesized in 1775 by the English chemist Joseph Priestly, who had previously identified oxygen. In the 1790s, Humphrey Davy, a contemporary of Priestly, studied the physiological properties of N_2O and tested its intoxicating effects upon himself and his friends. In 1844 Gardner Quincy Colton, an American showman, lecturer, and former medical student, administered N_2O as a general anesthetic to Horace Wells, a Connecticut dentist, for a molar extraction. Wells then attempted to promote its use, but was discredited following an unsuccessful demonstration to medical students. Recognizing N_2O as a weak general anesthetic, but good analgesic, Colton proselytized its use in dental surgery in the 1860s. Subsequently, Chicago surgeon Edmond Andrews combined N_2O with 20% oxygen to prevent asphyxiation while prolonging anesthesia. The N_2O/O_2 delivery system was perfected for easier and more reliable use in the early 20th century and gained widespread acceptance.

It should be emphasized that, for most of its first 100 years of dental application, N_2O was used as general anesthesia. Patients were rendered unconscious for 1 to 2 minutes, initially using N_2O only and later combined with O_2. The operation was performed quickly and with anticipation that the patient would regain consciousness shortly thereafter. Administration of N_2O remained potentially lethal until its usage shifted from anesthesia to analgesia and sedation in the second half of the 20th century, which could be achieved with much lower dosages.[24]

RISE IN USAGE

The earliest survey about N_2O use among US dentists appears to be a 1977 survey by the ADA. At that time, only 35% of dentists used N_2O in their practices.[25,26] By 1994, this number rose to 56%.[22] This number, however, does not provide a good insight into the prevalence of its use. For example, one third of the dentists confirming N_2O usage had not administered it to any of their patients in the foregoing 12 months, and only approximately 7% of patients reported having had N_2O administered. Due to a heterogeneity of services by dental specialty, N_2O use varied considerably with specialty. While 46% of all specialists reported its use, orthodontists appeared to never use it vs 85% of oral and maxillofacial surgeons who did.

Unfortunately, pediatric dentistry was not specifically identified in the 1994 ADA survey. A 1996 report by Wilson and colleagues revealed that N_2O was a popular pharmacologic agent used by 89% of pediatric dentists, with most using it more than 5 times per week.[27] Again, this does not inform us about the prevalence of usage as a fraction of the total pediatric patient population or as a fraction of the number of interventions performed.

In a 1999 survey of pediatric dentists in the southeastern United States, Carr and colleagues found that 86% of all the surveyed dentists used N_2O.[28] Although by 1999, 22% of dentists older than 50 never used N_2O, all pediatric dentists younger than 30-years-old had it in their office. The study also found that the N_2O use by all respondents combined had risen slightly in the preceding 5 years (70% remained unchanged, 18% increased, and 12% decreased or discontinued use).

Similar trends are revealed by 4 surveys undertaken between 1985 and 2000 as part of the Project on Usage of Sedative Agents by Pedodontists.[29-32] In 1985, more than half of all pedodontists (55%) used N_2O on 10% or fewer of their patients, about a quarter (23%) on 10-50% of their patients, and the remainder (22%) used it on more than 50% of their patients. The latter percentage stayed the same in all subsequent surveys. The balance between the first 2 categories of dentists shifted somewhat, however, so that by 2000, 47% used it on fewer than 10% of patients and just under one third (31%) used it on 10% to 50% of their patients. Based on these surveys, we can conclude that in the last quarter of the 20th century, there was a gradual rise in the usage of N_2O by dentists in general, as well as among pediatric dentists, such that by 1999 all incoming pediatric dentists were using it.

The data indicates a large variation in usage among pediatric dentists. Even when N_2O became more prevalent, the practice variation did not disappear or even

lessen. Houpt and colleagues have suggested that the decision on the type of sedation to be used, including N_2O, seems to depend more on the experience and bias of the individual practitioner than on patient needs and characteristics.[29,33] Similar conclusions can be drawn from the study by Carr and colleagues previously quoted. Not only did they find significant differences in usage among age groups, but practices varied dramatically within these groups. For example, approximately 18% of pediatric dentists older than 50 years used N_2O on every patient, 60% used it sometimes, and 22% never.[28] One can hypothesize that, as dentists mature, they also gain an understanding of child psychology, effective verbal and nonverbal communication skills, the art of persuasion, and leadership skills, enabling them to diminish or even delete the need for pharmacologic behavior management techniques.[7]

Carr et al. found that approximately 5% of dentists between 30 and 39 years old, 13% of those between 40 and 50-years-old, and 22% of those over 50 years old never used N_2O, which appear to confirm this expectation. But Carr et al. also found that the older generations of dentists were more likely than younger generations to increase rather than decrease or discontinue N_2O usage. This finding, however, also may reflect that a number of older dentists were perhaps still "discovering" the benefits of N_2O, whereas their younger colleagues were familiarized with N_2O during their dental education. Additionally, the oldest generation (>50 years old) was more likely than the 30- to 39-year-old generation to adopt a routine of always administering inhalation sedation (18% vs 13%).

CHANGES IN THE ACCEPTANCE OF DIFFERENT BEHAVIOR MANAGEMENT TECHNIQUES BY PARENTS

The rise in usage by pediatric dentists in the late 20th century was accompanied—and possibly stimulated—by a parallel rise in parental acceptance of behavior control methods. In the 1980s, parents became more sensitive to the treatment of children in the dental office, challenging traditional methods of management of pediatric behavior. In a 1984 survey, parents rated (1-10) nonpharmacologic techniques, with tell-show-do (**TSD**) as the most favored method of behavioral control, followed by positive reinforcement, voice control, mouth prop, physical restraint by assistant and by dentist, and hand-over-mouth.[34] By contrast, sedation (including sedation by means of N_2O) was listed as eighth best in acceptability, followed by general anesthesia (ninth) and papoose board (10th and last). In the event of an emergency in which patient behavior management was imperative, general anesthesia retained its same status, but sedation moved into fourth place.[35]

Seven years later (1991), in a pediatric dentistry survey listing N_2O as a separate entity out of 8 possible mo-dalities, N_2O was rated second in terms of parental acceptability following TSD; oral premedication and general anesthesia were seventh and eighth, respectively.[36] Notably, there was a quadruple, across-the-board approval of any technique with explanation by the dentist, regardless of the general approval level for that technique. This suggested that provider-patient communication had become a major determinant of parent approval.

The persistence of this trend toward parental acceptance of N_2O was underscored by a 2005 study assessing contemporary attitudes of parents toward the same 8 management techniques used by Lawrence and colleagues.[36,37] N_2O remained second to TSD, but general anesthesia showed a dramatic rise to third in acceptability. Changing perceptions of health care, such as increased familiarity with outpatient surgical services and increased drug marketing to the public through the printed press, television, and the Internet, may have led to widespread parental beliefs that pharmacologic behavior management is without risk of harm.[37]

Changes in parental acceptance of different management techniques paralleled changes in the parent-clinician relationship. In the mid-1980s, parents began to assume a more active role in the management of their children in the dental office and questioned long-held, standard treatment philosophies and modalities. Dentists were compelled to adjust their relationship and to better accommodate parental concerns. A 2002 survey by the American Academy of Pediatric Dentistry reported a general consensus among the responding diplomats that major parenting changes had occurred during their practice careers which had led them to shift their behavior management techniques to less assertive modes.[38] A 2007 survey confirmed this shift from a more discipline oriented style characteristic of older practitioners who possess higher expectations for patient cooperation to a "deferment" style more popular among younger dentists who more often prefer to leave disciplinary management to parents.[39] As a result, parents have sought and been given an active voice in their child's management. Whether their "requests," if honored, are always in the child's best interests, remains to be seen.

PREDOCTORAL DENTAL EDUCATION OF N_2O

The excellent safety record of N_2O for behavior management and increased parental acceptance for pharmacologic intervention may have driven N_2O usage upward in the last quarter of the 20th century, such that it has become a routine management component. In turn, this has impacted dental education. Not only are dental students now familiarized with the technique, it also has become a method to attain and extend a child's behavior "good time," to better accommodate students who work at a slower pace. This would seem to be a benefit for all parties involved, but on occasion may have an unexpected negative result.

It is the experience of the author that in the teaching environment, dental students may develop a clinic-imposed reliance upon N_2O for the management of

those pediatric patient displaying signs of apprehension or resistance. Such reliance might not be necessary for the more skilled and experienced clinician. As a result, students and recent dental graduates may not appreciate the nonpharmacological management techniques such as TSD, modeling, and positive reinforcement that may be all that is necessary for management. They may lack the self-confidence to work outside their educational comfort-zone. Fortunately, the current trend toward dental externship programs to supplement formal dental school clinical training via community clinics, hospitals, and private offices will expand student use and understanding of N_2O.

Guidelines for teaching N_2O in predoctoral education did not occur until 1971 with the publication of the *Guidelines for Teaching the Comprehensive Control of Pain and Anxiety in Dentistry* by the Council on Dental Education.[40] These guidelines resulted from a collaboration of the ADA, American Society of Dental Anesthesiology, and the American Association of Dental Schools. Prior to that time, "relative anesthesia" was presented as continuing dental education by Harry Langa, who published the first edition of his *Relative Analgesia in Dental Practice: Inhalation Analgesia and Sedation with Nitrous Oxide* in 1969.[11,41] It is noteworthy that the 1971 guidelines stated that N_2O inhalation procedures should only be taught after students had achieved increased levels of clinical experience and responsibility, and only after having become familiar with basic intravenous techniques, a view no longer held today.

The next set of educational guidelines, dating from 1989, acknowledged varying levels between dental schools regarding clinical experience of N_2O use to be achieved by students. In response, the guidelines established a numerical experience requirement of 15 documented patients prior to certification of competency, which was identical to that of intravenous sedation.[42] The 2007 update of Guidelines for Teaching Pain Control and Sedation to Dentists and Dental Students acknowledged that inhalation sedation was most often completed as part of predoctoral dental education and established a minimum of 14 hours, including a clinical component, during which competency would be achieved.[2] Records of didactic and clinical experience and the number of patients were to be maintained and available upon request to satisfy specific requirements for state inhalation sedation permits.

A 1989 ADA study of 59 dental schools surveyed the level of N_2O teaching. In nearly 12% of the responding schools, most students attained "familiarity" with N_2O sedation; in just over half of all schools (53%), the majority of students achieved "competency"; and in the remaining 36% of schools, most students attending those schools achieved "proficiency."[42] These 1989 frequencies were comparable to those attained in a study by Belanger and Tilliss a few years later.[43] They distinguished between "no training," "training at a basic competency level," and "training at a comprehensive level or proficiency." They found that 4% of responding dental schools (N=59) did not teach N_2O in the classroom, 9% did not provide clinical education, and 22% taught students to refer to a specialist for N_2O. Seventy percent of schools taught at a "basic competency" level and 61% of the schools attained basic competency in clinical application as well. Finally, 26% of schools sought to teach at a "comprehensive" level, and 9% aimed to teach at a "proficiency" level.

The findings of these 2 studies are contradicted by a 2004 study by Adair and colleagues.[44] They found that 47 of 48 responding schools taught N_2O in the classroom, while 1 school did not. But the clinical teaching level seemed to have decreased dramatically rather than increased. When clinical experience was defined as "at least one hands-on experience," as many as 32 schools (70%) did not teach N_2O (similar to general anesthesia, which was not taught in 31 schools). By contrast, only 4 schools did not teach "conscious sedation" (which, given the separate category of N_2O, must have referred to oral sedation). In addition to the 32 schools not providing clinical experience in N_2O, 12 more schools reported that only a quarter or fewer of their students had one hands-on experience with N_2O. Given the overall general usage of N_2O by practicing dentists, it would be rather disconcerting if these findings by Adair and colleagues are correct.

A different method of assessing the status of N_2O instruction in the undergraduate dental curriculum is to review successive editions of leading textbooks, such as the pediatric dental textbook *Dentistry for the Child and Adolescent*, which was first published in 1969 and is now in its eighth edition. The subject of N_2O first appeared in the second edition from 1974 (first edition, 1969[45]) under the header of "relative anesthesia" as a "tool" to address dental pain as well as the fear of dental pain.[46] The third edition (1978) acknowledged reported recent concerns about occupational exposure.[47] By the fourth edition (1983), N_2O was described as both an analgesic to control pain and a psychosedative drug to modify behavior.[48] For the first time, adverse affects of nausea, vomiting, and cautionary drug interaction were reported. In the fifth edition (1987), N_2O was relocated from the chapter on pain relief to a new chapter on pharmacologic management of patient behavior, where it has remained since.[49] By the sixth edition (1994) and subsequent seventh edition (2000), N_2O was presented as a pharmacologic behavior management tool independent of any prerequisite rapport-centered approach, such as positive reinforcement or TSD.[50, 51] It was simply stated that N_2O was used by 85% of pediatric dentists, without making any attempt at specifying whether these dentists used it all the time, occasionally, or rarely. No reference to the scientific literature was provided to support the stated frequency.

In the current eighth edition (2004), concerns of specific occupational hazards are limited. This may explain the low compliance regarding office monitoring. Similarly, potential drug interactions are reported as "negligible" due to the high concentration of oxygen used.[1]

CONCLUSION

After the analgesic qualities of N_2O were discovered in the 19th century, dental practitioners experimented with N_2O as a general anesthetic for almost a century, frequently pushing beyond physiologic tolerance levels. Its usage then shifted to that of an analgesic and subsequently to an inhalation sedative. The significantly reduced dosages needed to elicit sedation rendered the drug much safer and enabled dentists to administer N_2O with ever greater frequencies. Consequently, by the dawn of the 21st century, N_2O had become a routine component of dental care among US dentists.

Nitrous oxide has deservedly earned the respect of dental practitioners, particularly in the treatment of children. Even as a routine practice, however, N_2O use merits a periodic examination review to assure that its record of clinical safety and ethical soundness is sustained (for a more detailed discussion of the ethics of N_2O administration, the 2010 article by Levering & Welie[52]) The following 5 observations should be considered when making decisions about N_2O administration:

1. N_2O has an undisputed safety record when used alone at subanesthetic concentrations. When used in combination with other sedative drugs, however, such polypharmacy entails risks.
2. N_2O poses a risk of bioenvironmental exposure to the clinician, staff, and patients when ambient air is not routinely scavenged and monitored.
3. Students' clinical experience with N_2O varies between dental schools, and there is insufficient evidence that all graduates are fully competent in N_2O usage.
4. Today's parents are more accepting of pharmacologic means of behavior management, including N_2O, in the dental office, which is likely to impact patient management decisions.
5. The choice to use or not use N_2O should always be in the current best interest of the child; past usage of N_2O for any particular child is not a sufficient reason to continue its use.

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