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Feature Story
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Nitrous Oxide

Nitrous Oxide-Oxygen: A New Look at a Very Old Technique

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Inhalation sedation utilizing nitrous oxide-oxygen has been a primary technique in the management of dental fears and anxieties for more than 150 years and remains so today. Though other, more potent, anesthetics have been introduced, nitrous oxide is still the most used gaseous anesthetic in the world. Administered properly with well-maintained equipment, the nitrous oxide-oxygen technique has an extremely high success rate coupled with a very low rate of adverse effects and complications.

Discovered in 1772, nitrous oxide was, for almost 70 years, a recreational drug. It was not until Dec. 10, 1844, in Hartford, Conn., at a traveling “popular science” exhibition that the potential of nitrous oxide to relieve pain was appreciated. On that night, “Professor” Colton demonstrated nitrous oxide. Attending the performance was a local dentist, Horace Wells. Wells noted that one of the men who had volunteered to inhale nitrous oxide had seriously injured his leg but was apparently unaware of any pain. The next day, a reluctant Colton served as the anesthesiologist as another dentist, Dr. John Riggs, extracted a wisdom tooth from Dr. Wells’ mouth. After recovering from the effects of the nitrous oxide, Wells stated that he had been totally unaware of the procedure and that there had been no pain associated with it.1

Wells -- recognized by both the American Dental Association in 18642 and the American Medical Association in 18703 as the discoverer of anesthesia -- committed suicide while in jail on May 30, 1848, while under the influence of the anesthetic gas chloroform, to which he had become addicted.

Though other, more potent, anesthetics have been introduced, nitrous oxide remains the most used gaseous anesthetic in the world. It is commonly administered as a part of every general anesthetic technique for the purpose of enabling a lesser amount of a more potent (and usually more toxic) general anesthetic agent to be employed.

Surveys by the American Dental Association demonstrate that the percentage of American dentists employing nitrous oxide-oxygen (the procedure changed to include oxygen in the 1860s) is about 35 percent.4

Interestingly, nitrous oxide-oxygen has found an important niche in the area of emergency medicine.5 Under the proprietary names Entonox and Dolonox, nitrous oxide-oxygen (in a 40 percent to 60 percent ratio), is employed by paramedical personnel in the prehospital management of pain associated with acute myocardial infarction.6 In some areas of the world, it is used in emergency medicine in lieu of opioid analgesics for the management of painful injuries.

Technique

The technique for administration of nitrous oxide-oxygen inhalation sedation has changed little during the past several decades. One of the most important safety features associated with the technique is the ability of the dentist or dental hygienista to administer to a patient the precise amount of nitrous oxide required to provide the desired level of central nervous system depression (sedation). This ability is termed “titration,” and it represents the most important safety feature of this technique. When titrated properly (Table 1) the success rate of nitrous oxide-oxygen inhalation sedation is extremely high. Unpleasant side effects --

such as nausea, vomiting, and bizarre behavioral responses -- do not occur when titration is performed. The administration of a fixed concentration of nitrous oxide-oxygen (for example 50 percent to 50 percent) routinely to all patients at each visit simply makes no sense given the ease with which titration may be carried out. The above-mentioned side effects are much more likely to be observed when titration is not employed.

The recommended technique of administration of nitrous oxide-oxygen inhalation sedation for the cooperative adult or child patient (a patient who willingly accepts the nasal hood) is presented in Table 1.7

Properly employing the technique described described above will allow the overwhelming majority of apprehensive dental patients to be successfully sedated, receiving their dental treatment in a much more comfortable and stress-free environment. Review of patient records from more than 29 years of administration of nitrous oxide-oxygen inhalation sedation at the University of Southern California School of Dentistry demonstrates that the typical inhalation sedation patient (middle of the bell-shaped curve) requires from 30 percent to 40 percent nitrous oxide to achieve ideal sedation (Figure 1).7

It is important to note that there are patients at either end of this normal distribution curve who respond well to significantly lower concentrations of nitrous oxide (hyperresponders -- left side of the curve), while others require significantly higher levels of nitrous oxide to achieve the same clinical effect (hyporesponders). Titration enables the dentist to adequately sedate all of these patients.

In the precooperative pediatric patient (younger than 5) acceptance of the nasal hood is not likely. Indeed, with a screaming or crying combative young patient, it is difficult to employ inhalation sedation successfully. In addition to the difficulty in placing the nasal hood in this situation, the screaming/crying patient is primarily breathing through his or her mouth. In the hands of a trained pediatric dentist, an acceptable technique is placement of the nasal hood over the mouth of the screaming/crying patient. In this manner, the patient receives large amounts of nitrous oxide-oxygen, which eventually leads to his or her calming down, at which time the nasal hood is repositioned on the nose and treatment commenced. This procedure is repeated as often as needed.

The Equipment

Although the technique of nitrous oxide-oxygen delivery has changed little, during the past decades the inhalation sedation machine has undergone considerable revision. Despite the introduction of the ester-type local anesthetics (e.g., procaine hydrochloride) into dental practice in 1904, nitrous oxide continued to be administered as the sole agent in general anesthesia. The administration of 100 percent nitrous oxide produced what is called "anoxic anesthesia." It wasn't until the introduction in the late 1940s of the first amide local anesthetic -- lidocaine hydrochloride -- that the need for nitrous oxide to provide pain control disappeared. Langa demonstrated that nitrous oxide in combination with oxygen would provide excellent "relative analgesia," which in combination with local anesthesia provided the dental patient with pain-free treatment 8 The ability of the inhalation sedation unit to deliver 100 percent nitrous oxide became a potential liability. The American Dental Association's Council on Dental Materials, Instruments, and Equipment adopted an Acceptance Program for inhalation sedation units that permitted the doctor to better evaluate those units being considered for purchase.9 The primary emphasis of this program has been the addition of safety features to these units aimed at making it difficult, if not impossible, to administer less than 20 percent oxygen to the patient. To receive a satisfactory classification, the manufacturer had to submit its devices to the Council on Dental Materials, Instruments, and Equipment for evaluation. The council publishes a listing of acceptable devices in the Journal of the American Dental Association, in the ADA Guide to Dental Therapeutics,10 and on the ADA Web site, www.ada.org.

The many safety features incorporated into the modern inhalation sedation unit are listed in Table 2.

Another significant, and more recent, change relates to the technology used to control the precise flow of gasses delivered through the inhalation sedation unit. Although the old flow tube flowmeter technology is still available, it is being replaced by the state-of-the-art digital electronic flow control devices, such as the

Centurion Mixer and Digital MDM (Figure 2). Both of these devices are percentage devices and overcome the limitations of the older flow tube technology. The devices have resolution of the gas flow in increments of 0.1 liter per minute, and the total flow and percent of oxygen are displayed digitally, eliminating the guesswork or calculations required with simple flow tube devices. The ability to clean the front panel with just a wipe reduces the potential of cross patient infection, an issue associated with the crevices created by knobs and levers. Patient safety is ensured with built-in alarms for all gas depletion conditions along with servo control of the gas delivery (what you see is what you get). Continuous internal self-monitoring of all operational parameters by the device frees the practitioner to concentrate on the patient's needs. The device alerts the practitioner or staff to unusual parameters requiring attention, similar to those seen in larger hospital-based systems.

The digital units deliver pure oxygen during the "flush" function by electronically shutting off the nitrous oxide flow, as opposed to the flow tube units, which only dilute the nitrous oxide delivered. Again, the removal of extra steps in shutting down the nitrous oxide supply before pressing the "flush" button is removed and greatly simplifies the practitioner's tasks.

The units contain flashing LEDs to afford the practitioner a simple method of ensuring that the individual component gas is flowing and that the relative ratio and amount of flow is correct. Additionally, the digital unit provides the capability of displaying the flow rate of either of the constituent gasses. The nonsilenceable alarm function for oxygen depletion ensures patient safety. The air intake valve located on the bag tee provides room air to the patient whenever the patient's breathing demand is greater than the combined output of the mixer head's settings and reservoir bag volume.

Various models of the electronic gas mixing head allow mounting as a wall unit, portable unit, countertop unit, or as a flush-mount unit in modern cabinetry. Digital heads have the most flexibility, especially when combined with various remote bag tee options provided by the manufacturer. The units are fully compatible with central gas supply systems such as the popular Flo-Safe Manifold, Centurion Gas Manifold, and all existing scavenging systems. It is available with the American Dental Association recommended 45 liter per minute scavenging control valve in various mounting configurations. 11

Electronic digital administration heads for delivery of conscious sedation advance the art of dentistry. The digital heads once considered the wave of the future are the standard today. The digital accuracy and exacting control is highly recommended for patient comfort and safety.

Current Concerns About Nitrous Oxide

Several concerns have been addressed regarding the safety of inhalation sedation with nitrous oxide-oxygen inhalation sedation. These include the problem of abuse of nitrous oxide by health care professionals, sexual awareness related to nitrous oxide, and potential biohazards of chronic exposure to trace anesthetic gas.

Abuse of nitrous oxide by health care professionals: Nitrous oxide causes euphoria and, therefore, as Sir Humphrey Davy discovered in 1798, has a potential for abuse.12,13 This abuse is usually not as addictive as some drugs, but nonetheless can be a steppingstone to other drugs and can cause incapacitation of the affected person. Nitrous oxide should be given the same respect given to all drugs.14,15 When chronically abused, nitrous oxide can have serious health consequences.16

The typical abuser of nitrous oxide is usually older and probably from the middle to upper class. If he or she has an inhalation sedation unit available, it has probably been altered in an attempt to deliver a higher concentration of gas. A dentist living in Colorado placed a blanket over his head to increase the concentration even more. He became asphyxiated and could not be revived. Chronic inhalation (abuse) of nitrous oxide may lead to various neuropathies. This is particularly concerning if the loss of tactile sensation is associated with interference with their occupation, i.e., dentist. The neuropathy is generally reversible but can be permanent.

Nitrous oxide is used for mood alteration, sedation, and analgesia. It is the weakest of all general anesthetic agents. In the right circumstances, it has the potential to cause unconsciousness.

Sexual awareness related to nitrous oxide: There have been reports of sexual abuse of patients while under the influence of a variety of anesthetics.17-19 As expected, nitrous oxide has also been associated with scattered reports of impropriety between male practitioners and female patients. Nitrous oxide does cause euphoria and, in high concentrations, dreaming hallucinations and, as described by Sir Humphrey Davy in 1798, “voluptuous sensations.” The cases of record always involve three elements that place the practitioner at risk: treating a patient without an assistant in the operatory, high concentrations of nitrous oxide, and failure to titrate the patient to avoid the extension beyond their range of therapeutic sedation.

Nitrous oxide requires hosing that can drape around the shoulders for retention of the mask. It is important to allow the patient to adjust the mask on his or her face and to help the patient understand that it is connected to the hosing. The hosing on a euphoric patient can be misconstrued to be an inappropriate contact. Also, the patient should be allowed to fully recover. It may take longer than three to five minutes. Jastak and Malamed have reported a series of cases involving nitrous oxide and sexual phenomena.17 Malamed reports in an unpublished survey that a percentage of dental hygiene students reported increased feelings of sexuality and/or arousal while under the effects of nitrous oxide.20 They also reported some instances of orgasm. Nitrous oxide should be employed with confidence. Employing simple guidelines will ensure there are no difficulties with any sexual issues and the administrator of nitrous oxide.

Potential biohazards of chronic exposure to trace anesthetic gas: Nitrous oxide is found naturally in the atmosphere in minute quantities. It is quickly reversible in action, but is it totally harmless?

Little was known about the possible effects of inhalation of minute amounts of anesthetic vapors until the late 1960s. Until this time, little was done to eliminate anesthetic vapors being delivered into the ambient air from the anesthesia machines. In 1967, Vaisman21 published the results of a survey of Russian anesthesiologists in which it was demonstrated that they suffered a higher incidence of irritability, headache, fatigue, nausea, pruritus, spontaneous abortion, and fetal malformation than non-operating room personnel. It must be emphasized that in these studies nitrous oxide was but one of many gases under investigation. Because it is the most commonly used inhalation anesthetic, nitrous oxide will be found in all samples of air taken from operating rooms. It is used in conjunction with oxygen and other more potent inhalation anesthetics such as isoflurane, desflurane, and sevoflurane. Therefore, it has been impossible to separate the effects of any one of these gases from the others. Because of the special nature of dental practice, in which virtually the only inhalation anesthetic employed is nitrous oxide, the findings of these operating room studies were not applicable to the dental profession.

In the United States, Cohen and colleagues22,23 published articles dealing with anesthetic health hazards in the dental setting. One article contained a study that surveyed more than 50,000 dentists and dental assistants who were exposed to trace anesthetics. The results suggested that long-time exposure to anesthetic gases could be associated with an increase in general health problems and problems with the reproductive system in particular. While this study was retrospective in nature, it only fueled the concern regarding the safety of nitrous oxide in the dental office. Unfortunately, this “study” did not contain any measured data of these trace gases that were involved in any of the environs reported.

In 1974, Bruce, Bach, and Arbit24 investigated the possibility of nitrous oxide affecting perceptual cognition and psychomotor skills of personnel exposed to varying concentrations of the gas. They reported that just hours of exposure to as little as 50 ppm could result in audiovisual impairment. Despite multiple attempts to duplicate their results, all efforts failed. The National Institute of Occupational Safety and Health became interested in these studies and established 50 ppm as the maximum exposure limit for personnel in the dental setting. It was determined that 25 ppm was achievable in the operating room, and therefore this became the standard for that setting. Multiple attempts to reproduce the research results of Bruce, Bach, and Arbit have failed;25 interestingly, these researchers have retracted their conclusions, indicating the results were not based on biologic factors.26

The results of this “research,” as one would expect, caused a concern and subsequent decline in the use of nitrous oxide. Indeed, there was alarm in the manufacturing and equipment industry for nitrous oxide that bordered on a crisis. In 1995, a worldwide literature search on the topic of biohazards associated with nitrous oxide use was conducted by Clark.27 Eight hundred and fifty citations were retrieved, of which 23 met the predetermined criteria for scientific merit. The conclusion drawn from this literature review indicated that there was no scientific basis for the previously established threshold levels for the hospital operating room or the dental setting. This research became the impetus for a meeting of interested parties representing dentistry, government, and manufacturing. A result of the September 1995 meeting, sponsored by the American Dental Association's Council of Scientific Affairs and Council of Dental Practice, was the formal position statement that a maximum nitrous oxide exposure limit in parts per million has not been determined.28

The specific biologic issue is the inactivation of methionine synthetase. This enzyme is linked to vitamin B-12 metabolism. Vitamin B-12 is necessary for DNA production and subsequent cellular reproduction. Nitrous oxide does affect methionine synthetase and does, in high concentration and with long exposure (longer than 24 hours), have an effect on reproduction.29 However, to date there is no evidence that a direct causal relationship exists between reproductive health and scavenged low levels of nitrous oxide.30,31 Sweeney and colleagues32 were the first to link reproductive problems in humans with chronic nitrous oxide exposure. He used a sensitive test -- the deoxyuridine suppression test -- to accurately determine the first signs of this biologic effect in humans. Sweeney found that chronic exposure levels of 1,800 ppm of nitrous oxide did not exert any detectable biologic effect in humans. Sweeney suggests that 400 ppm is a reasonable exposure level that is both attainable and significantly below the biologic threshold.

Today, it is below the standard of care not to have a scavenging nasal hood.27 The scavenging nasal hood is a double mask: an inner mask contained within a slightly larger outer mask. The inner mask receives a fresh supply of nitrous oxide-oxygen from the inhalation sedation unit and delivers gas to the nose of the patient through tubes that are slightly larger in diameter than the other tubes. The outer, slightly larger, mask connects to slightly smaller tubes that connect with the vacuum system. On exhalation through the nose all exhaled gases are vented into the outer nasal hood and then, via the vacuum, are carried away from the patient and the treatment area.

Two of the most common causes of nitrous contamination in the office are from patients' talking and mouth breathing. The clinician should recognize this problem and attempt to modify the situation to make the interaction with the patient as brief and concise as possible. The use of a rubber dam is highly effective at decreasing trace nitrous oxide exposure.

Monitoring of trace nitrous oxide: The most accurate and effective method of determining nitrous oxide levels in ambient air is through an infrared nitrous oxide analyzer.33 The infrared analyzer can detect gases from the previously mentioned 1 ppm to an upper limit of 2,000 ppm. These devices are very expensive but can be rented from a gas service company. A gas supplier will have the resources available for dentists to rent an infrared spectrophotometer for nitrous oxide analysis.

In 1997, the American Dental Association published recommendations for responsible maintenance and monitoring of nitrous oxide and its equipment. They are listed in Table 3.28

Summary

Inhalation sedation utilizing nitrous oxide–oxygen has been a primary technique in the management of dental fears and anxieties for more than 150 years and remains so today.

Administered properly with well-maintained equipment, the technique has an extremely high success rate coupled with a very low rate of adverse effects and complications.

Notes

a. The administration of nitrous oxide–oxygen inhalation sedation by trained dental hygienists is permitted by some state dental boards

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Table 1. Inhalation Sedation Technique7

1. A 5 or 6 Lpm (liter per flow minute) of 100 percent oxygen is established, and the nasal hood is placed on the patient’s nose. The patient is instructed to adjust the mask as needed for comfort.

2. If necessary, the flow rate is adjusted (more, less, the same) while the patient is breathing 100 percent oxygen. The patient must be able to breathe comfortably, in and out, through his or her nose with the nosepiece in position.

3. A flow of nitrous oxide is started, at approximately 20 percent initially. Nitrous oxide is then added in ~10 percent increments every 60 seconds until an ideal sedation level* is reached.

4. When the patient states that he or she feels pleasant and more relaxed, the ideal level of clinical sedation* has been achieved.

5. Once the ideal level of sedation* is achieved, local anesthetic is administered and the planned dental/surgical procedure completed.

6. Nitrous oxide flow is terminated, and the patient is permitted to breathe 100 percent oxygen at a flow rate equivalent to the established Lpm for the patient. This may be started earlier than at the absolute completion of the procedure to ensure a more expedient recovery. Oxygen is given for minimally three to five minutes, longer if clinical signs of sedation persist.

7. The patient may be dismissed from the dental office unescorted if it is the doctor's belief that he or she is completely recovered from sedation.

* Ideal sedation has been achieved when the patient states that he or she is experiencing some or all of the following: feeling of warmth throughout his or her body, numbness of the hands and feet, numbness of the soft tissues of the oral cavity, a feeling of euphoria, and a feeling of lightness or of heaviness of the extremities. Note that not all patients will experience the same symptoms.

Table 2. Safety Features Incorporated Into Modern Inhalation Sedation Units

Alarm

Color coding

Diameter index safety system

Emergency air inlet

Lock

Minimum oxygen liter flow

Minimum oxygen percentage

Oxygen fail-safe

Oxygen flush button

Pin index safety system

Quick-connect for positive-pressure oxygen

Reservoir bag

Table 3. ADA Recommendations for Maintenance and Monitoring of Nitrous Oxide-Oxygen and Equipment28

1. The dental office should have a properly installed nitrous oxide delivery system. This includes appropriate scavenging equipment with a readily visible and accurate flow meter (or equivalent measuring device), a vacuum pump with the capacity for up to 45 liters of air per minute per workstation, and a variety of sizes of masks to ensure proper fit for individual patients.

2. The vacuum exhaust and ventilation exhaust should be vented to the outside (for example, through the vacuum system) and not in close proximity to fresh-air intake vents.

3. The general ventilation should provide good room air mixing.

4. Each time the nitrous oxide machine is first turned on and every time a gas cylinder is changed, the pressure connections should be tested for leaks. High-pressure line connections should be tested for leaks quarterly. A soap solution may be used to test for leaks. Alternatively, a portable infrared spectrophotometer can be use to diagnose an insidious leak.

5. Prior to first daily use, all nitrous oxide equipment (reservoir bag, tubings, mask, connectors) should be inspected for worn parts, cracks, holes, or tears. They should be replaced as necessary.

6. The mask may then be connected to the tubing and the vacuum pump turned on. All appropriate flow rates (that is, up to 45 L/min. or per manufacturer's recommendations) should be verified.

7. A properly sized mask should be selected and placed on the patient. A good, comfortable fit should be ensured. The reservoir (breathing) bag should not be over- or underinflated while the patient is breathing oxygen (before the administration of nitrous oxide).

8. The patient should be encouraged to minimize talking and mouth breathing while the mask is in place.

9. During administration, the reservoir bag should be periodically inspected for changes in tidal volume; and the vacuum flow rate should be verified.

10. On completing administration, 100 percent oxygen should be delivered to the patient for five minutes before the mask is removed. In this way, both the patient and the system will be purged of residual nitrous oxide. An oxygen flush should not be used.

11. Periodic (semiannual interval is suggested) personal sampling of dental personnel, with emphasis on chairside personnel exposed to nitrous oxide, should be conducted (for example, through use of diffusive sampler [dosimeter] or infrared spectrophotometer).

Legends

Figure 1. Normal distribution curve for nitrous oxide-oxygen inhalation sedation.

Figure 2. Digital electronic flow control device, Digital MDM. Photograph courtesy of Matrx (Orchard Park, N.Y.).

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