Nitrous Oxide: Use and Safety
A Peer-Reviewed Publication
Written by Ian Shuman, DDS, MAGD, AFAAID

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In dentistry, nitrous oxide is the most commonly used inhalation anxiolytic and sedation adjunct. It reduces anxiety and pain, and memory of the treatment experienced. It is a valuable component of the armamentarium available to clinicians. When used correctly, it is predictable, effective, and safe.

Educational Objectives
The focus of this clinical study is to provide the dental professional with the steps needed to deliver nitrous oxide in a safe and efficacious manner. After reading this article, the reader should be able to:
1. Review the history of nitrous oxide
2. Understand the properties of nitrous oxide
3. Know the safety recommendations
4. Have the ability to deliver nitrous oxide in a safe manner and know the contraindications

Author Profile
Ian Shuman, DDS, MAGD, AFAAID, maintains a full-time general, reconstructive, and esthetic dental practice in Pasadena, Maryland. Since 1995, he has lectured and published on advanced, minimally invasive techniques, while teaching procedures to thousands of dentists and developing many of the methods. Dr. Shuman has published numerous articles on topics including adhesive resin dentistry and minimally invasive restorative, cosmetic, and implant dentistry. He is a fellow of the Pierre Fauchard Academy.

Author Disclosure
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Abstract
In dentistry, nitrous oxide is the most commonly used inhalation anxiolytic and sedation adjunct. It reduces anxiety and pain, and memory of the treatment experienced. It is a valuable component of the armamentarium available to clinicians. When used correctly, it is predictable, effective, and safe.

Introduction
Officially known as dinitrogen monoxide by the International Union of Pure and Applied Chemistry (IUPAC), nitrous oxide (an oxide of nitrogen) is a small inorganic chemical molecule with the formula N₂O.¹ It is commonly known as laughing gas, nitrous, nitro, NOS, sweet air, protoxide of nitrogen, and hyponitrous oxide. At room temperature, it is a colorless, non-flammable gas, with a slightly sweet odor and taste.² It is used in surgery and dentistry for its anxiolytic and analgesic effects. As a general anesthetic, it is very weak and generally is not used as a single agent but is often used as a carrier gas with oxygen in combination with more potent general inhalational gases for surgical anesthesia.³ It is known as “laughing gas” due to its euphoric effects, a property that has led to its recreational use as a dissociative anesthetic. As an industrial gas, it is used as an oxidizer in rockets and in auto racing to increase engine output power. It is also a foaming agent for canned whipped cream in the food industry.

History
The history of nitrous oxide begins with its isolation by the theologian and scientist Joseph Priestley in 1772.⁴ In 1798, Humphrey Davy, an English chemist, noted the analgesic effects, and in 1800 he published on the history, chemistry, physiology and recreational use of nitrous oxide.⁵ In his text, Humphrey mentions, “As nitrous oxide appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place.” Unfortunately, surgeons of this era failed to take note, and the gas was used primarily for public entertainment. Inhalation of nitrous oxide for recreational use began as a phenomenon for the British upper class in 1799, known as “laughing gas parties.” In 1844, Horace Wells, an American dentist, realized the therapeutic applicability of the gas after self-administration. His associate, William Morton, became its chief proponent and drove inhalation anesthetic use forward.⁶ Today, nitrous oxide is used in dental facilities worldwide.

Physical Properties
Nitrous oxide gas is produced by heating ammonium nitrate crystals to 250°C, then scrubbing, compressing, and liquefying the gas before placing it in pressurized tanks.⁷ Present as both liquid and gas in the tank, it vaporizes at room temperature as it is used. The color of the nitrous oxide tank varies by country. In both the United States and Canada, nitrous oxide tanks are blue, with the pressure measuring approximately 750 pounds per square inch (psi) at 70°C (less at lower temperatures), irrespective of the size of the tank or the quantity of nitrous oxide remaining in it. Once there is no liquid phase remaining in the tank, the pressure will begin to drop. The shoulder of the nitrous oxide cylinder is marked with information including, but not restricted to, the brand, manufacturer’s test date and serial number, inspector’s mark, Department of Transportation (DOT) specifications, and service pressure (figure 1). The oxygen tank used during nitrous oxide/oxygen sedation is green in the United States and white in Canada, with other colors used outside North America.

Physiology
The mechanism by which anesthetic gases produce general anesthesia is unknown. The leading theory suggests that gases bind to proteins within neuronal membranes and modify ion fluxes and subsequent synaptic transmission.⁸ Unlike other anesthetics, nitrous oxide produces a mild analgesic effect at sub-anesthetic concentrations. The mechanism for this effect most likely involves an interaction with the endogenous opioid system because it is abolished by administration of the opioid antagonist, naloxone. The strongest evidence for these analgesic effects is that nitrous oxide stimulates the release of enkephalins, which bind to opioid receptors that trigger descending noradrenergic pathways.⁹ This interaction with the endogenous opioid system may account in part for the abuse potential attributed to nitrous oxide. The gas also directly modulates a broad range of ligand-gated ion channels.¹⁰ It may act to imitate nitric oxide (NO) in the central nervous system, and this may be related to its analgesic and anxiolytic properties.¹¹

Nitrous oxide possesses a minimum alveolar concentration (MAC) of 104%, making it impossible to induce general anesthesia below a concentration of 100% and without hyperbaric conditions. Nitrous oxide sedation appropriately administered is safe for normal, healthy patients, and its effects on the cardiovascular and respiratory systems are minimal. Although a mild myocardial depressant, its minor central sympathetic stimulatory effect offsets this.

Nitrous oxide has a low blood/gas partition coefficient (0.47), so only minimal amounts dissolve in blood. The fast onset and quick recovery seen with nitrous oxide/oxygen seda-
tion is due to the rapid diffusion and saturation in blood. At a concentration of 50% to 70%, rapid uptake occurs from the alveoli to the pulmonary circulation and simultaneously creates a vacuum in the lungs that helps to pull more gas into the alveoli. 

\[ \text{N}_2\text{O} \text{ is a useful adjunct with general anesthetic inhalants. When used in combination, nitrous oxide and the anesthetic agent are drawn into the lungs, providing a faster onset and quicker recovery, a function of concentration gradients. However, after administration is terminated, nitrous oxide is rapidly diffused back into the lungs along with oxygen and other gases. Due to this, oxygen exchange from the pulmonary circulatory system is impaired, which can result in diffusion hypoxia. When inhalation of high concentrations of nitrous oxide is discontinued, high partial pressure in blood rapidly transfers nitrous oxide to the alveoli. This dilutes the partial pressure of oxygen in the alveoli and may lead to hypoxemia. For this reason, it is conventional practice to provide the patient with 100% oxygen during the (approximately) first five minutes following discontinuation of nitrous oxide.} \]

This concern is more theoretical than clinical, however. Hypoxemia is significant for only a matter of minutes and has been documented only when high concentrations (>70%) have been delivered by full mask or by endotracheal tube. These conditions cannot be met with the use of conventional dental nitrous oxide machines with nasal masks, and any tendency for diffusion hypoxia is usually inconsequential. Dental N2O units will not allow greater then a 70% N2O to 30% O2 ratio as a safety feature and avoid accidental administration of greater then a 70% N2O gas. Nevertheless, providing 100% oxygen toward the end of a dental appointment has other benefits and is advocated. This allows discontinuation while providing a waning placebo influence, and it allows expired nitrous oxide to enter the scavenging apparatus of the machine, limiting exposure of the staff and practitioner to the gas being exhaled, which is sound environmental practice.

**Indications and Benefits**

Nitrous oxide is the most commonly used inhalation anesthetic/sedative used in dentistry and has an excellent safety record. In medicine, the number of office-based anesthesia procedures is increasing more rapidly than are hospital-based procedures. Nitrous oxide/oxygen conscious sedation is frequently used in oral surgery, particularly in the extraction of third molars, periodontal surgery, implant placement, and in patients with behavioral or developmental issues.

**Anxiolysis**

Anxiolysis is the prevention or reduction of anxiety. An anxiolytic is a medication or other intervention that inhibits anxiety. The main indication for nitrous oxide is to diminish anxiety and fear in patients, and this is often accomplished using low-dose \[ \text{N}_2\text{O} \] and high-dose oxygen. Low-dose \[ \text{N}_2\text{O} \] can also induce relaxation of psychological tension in dental patients who have dental phobias. Also, high-dose oxygen contributes to manage pre-syncope due to pain stimuli.

In particular, phobic and fearful children who are too young and/or unable to cooperate or overcome their fears are candidates...
Conscious Sedation

Conscious sedation is the use of a combination of drugs to induce relaxation and provide some analgesia during a medical or dental procedure. Nitrous oxide/oxygen reduces pain and anxiety in anxious and fearful patients, including those who are phobic and unreceptive to other techniques and for whom the only other alternative may be general anesthesia. Conscious sedation has been found to be efficacious, reliable, and more cost-effective than general anesthesia. Pharmacological agents and techniques used in dentistry for sedation include enteral sedation with benzodiazepines or intravenous conscious sedation using a variety of agents including benzodiazepines, narcotic analgesics, and hypnotic/amnesic agents. With multiple drug regimens, extra caution must be exercised.

In surveys of patients not visiting the dentist, fear of needles and pain were responsible for up to 28% and 21% of adult patients respectively. A number of techniques are available to reduce fear and anxiety and increase cooperation with treatment. These include behavioral techniques and communication. Hypnosis has been used to reduce fear, the perception of pain, and to alter memory, although not all patients are suggestible for hypnosis. Acupuncture and acupressure have also been used.

Functional and cognitive deficits can make dental treatment difficult for special needs patients. As with fearful patients, behavioral interventions may be helpful. In some circumstances, physical support or protective stabilization is used. Nitrous oxide/oxygen sedation is an effective method to enable treatment in patients with reduced mental development as well as other special needs patients. Consideration must be given to the ability of the patient to communicate and understand the procedure.

Contraindications

As with any inhalation drug, there are both relative and absolute contraindications with N2O. These include patients with respiratory illnesses such as chronic obstructive pulmonary disease (COPD) and asthma, nasal obstruction, and pregnancy, among others.

COPD: Patients with chronic obstructive pulmonary disease have both a reduced ability to move gases into and out of the lungs because of reversible bronchospasm and irreversible bronchial obstruction. Hypoxemia and hypercarbia can result from chronic hypoventilation or poor gas exchange across the respiratory membranes. Some authorities suggest that nitrous oxide should be avoided in patients who have significant chronic obstructive pulmonary disease. Reasons cited include depression of hypoxic drive: since high oxygen concentrations are delivered with nitrous oxide, its use may remove the stimulus for hypoxic drive. However, if the principles of moderate sedation are followed, the patient can always be instructed to breathe more deeply.

Asthma: All inhalation agents share a tendency to increase respiratory rate but decrease tidal volume. Their net influence on ventilation is reflected as the degree of hypercapnia that occurs during administration. Nitrous oxide is distinguished from other agents in that it does not reduce net ventilation. Since N2O is not irritating to the tracheobronchial tree, asthma is not a contraindication to the use of N2O, provided the patient is not having an attack. In fact, there is a benefit to administering nitrous oxide since in many asthmatics, the primary precipitant appears to be emotional stress, especially in children. However, no dental procedure should be attempted if the patient is having respiratory difficulty due to asthma.

Nasal obstruction: The inability to use a nasal mask is an absolute contraindication to the use of nitrous oxide. Generally, such patients fall into one of two categories: (1) those who

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<tr>
<td>1. Mildly apprehensive patient</td>
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<td>2. The frightened child</td>
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<td>3. To reduce awareness of time and fatigue</td>
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<td>4. To reduce dental stress</td>
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<td>5. To control gagging</td>
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<td>5. Immune-compromised patient</td>
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<td>7. Patient using marijuana or hallucinogenic drugs</td>
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<table>
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<th>Absolute contraindications to N2O</th>
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<tr>
<td>1. Nasal obstruction</td>
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<td>2. Completely uncommunicative, either due to disability or language barrier</td>
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<td>3. Increased intracranial pressure</td>
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<td>4. As a substitute for local or general anesthesia</td>
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<td>5. Patient refusal</td>
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<td>6. Active substance abuse or recovered substance abuser</td>
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<td>7. Lack of gas recovery affecting dental team</td>
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cannot inhale adequately through the nose because of anatomic and/or disease-induced nasopharyngeal obstructions, and (2) those who cannot tolerate and sustain placement of the nasal mask because of psychological and/or cognitive disturbances. Examples include patients who are severely phobic, cognitively impaired, and pediatric patients. Additional examples include patients with a deviated septum, nasal polyps, upper respiratory infection, allergic rhinitis, and severe sinusitis. In this latter regard, any compromise in patency of the eustachian tube may lead to pressure increases within the middle ear, as previously mentioned. In fact, it has been suggested that any recent surgery of the ear presents a contraindication for nitrous oxide use.35

Any nasal obstruction will severely restrict the patient’s ability to breathe through the nose. Since nitrous oxide must be administered via a nasal mask, this becomes a relative contraindication depending on the severity of the obstruction. Patients who are “mouth breathers,” either due to nasal restriction or simply from habit, do not do well attempting to breathe through the nasal mask and often can not exchange well enough nasally to be comfortable.

Multiple sclerosis: Multiple sclerosis (MS) is a disease characterized by nerve demyelination, especially in the central nervous system. Neurologic symptoms of weakness, incoordination, paresthesia, and speech disturbances are common. Neither occupational exposure to anesthetic agents nor general anesthesia or usage of nitrous oxide has any impact on MS risk and is safe also for people with a genetic susceptibility to the disease. However, further studies would be valuable in order to clarify whether other forms of organic solvents contribute to the triggering of MS.36

Pregnancy: Nitrous oxide readily enters fetal circulation, and because of the possible toxicity of N₂O to cells undergoing mitosis, pregnant patients, especially in the early weeks of pregnancy, should not receive nitrous oxide electively. However, necessary emergency dental care should not be denied a pregnant patient, and if it is determined that N₂O is necessary to reduce stress, it may be used following consultation with the obstetrician. Widely used in Europe as a labor analgesic, nitrous oxide (N₂O) is making a dramatic return in the United States.37

Psychiatric patients: Psychiatric patients may present sedated due to their normally prescribed medication. It is best to consult the patient’s psychiatrist and/or treating physician before administering N₂O. If permitted, these patients should be titrated carefully, with close monitoring, as their reactions may be unpredictable.

Inability to communicate: Since much of the patient monitoring with N₂O conscious sedation is done verbally, being unable to communicate with the patient becomes a contraindication to the use of N₂O. This would include severely mentally challenged patients, very young patients, language barriers, or any condition that prevents easy exchange of thoughts between doctor and patient.

Hallucinogenic drugs: The use of hallucinogenic drugs such as marijuana is contraindicated for N₂O. Marijuana can enhance an already pleasant situation, and conversely increase the dysphoria of an already stressful situation. Following heavy use of marijuana, the drug may remain in the circulation for seven or more days due to its very long half-life. Hallucinogenic drugs act in a similar manner, only with a great deal more intensity, and patients may experience frightening hallucinations.

Intracranial pressure: Nitrous oxide has been shown to increase intracranial pressure in patients with certain injuries and intracranial disorders. Therefore, N₂O should not be administered to these patients. The role of vascular tone in determining cerebral perfusion pressure is increasingly being appreciated. It has been suggested that zero flow pressure, the arterial pressure at which blood flow ceases, represents the effective downstream pressure of the cerebral circulation. Nitrous oxide is a cerebral vasodilator and may therefore decrease zero flow pressure and increase cerebral perfusion pressure. However, these effects may be opposed by the increase in intracranial blood volume produced by cerebral vasodilation.

Highly apprehensive patients: Since N₂O is a relatively weak agent, it should not be used alone in an apprehensive patient, or as a substitute for anesthesia.

Blockages: Because nitrous oxide has a solubility coefficient that is 35 times higher than nitrogen, it can quickly displace nitrogen in any closed cavity, dramatically increasing the pressure within. Therefore, conditions such as blocked Eustachian tubes, blocked bowel, acute blocked sinuses and pneumothorax that allow a rapid pressure increase in a closed body cavity, leading to pain, contraindicates the use of N₂O.

Depression of bone marrow activity: Exposure to N₂O causes a depression of bone marrow activity, resulting in a reduction in the production of erythrocytes and leukocytes. However, since normal marrow contains a “store” of mature cells sufficient to supply several days’ needs, and the marrow recovers to return to production within 3 to 4 days, no hemotologic change is seen following an isolated anesthetic or conscious sedation exposure to nitrous oxide. However, a second exposure within this period of time will extend inhibition of synthesis, which may exceed the safety factor of stored cells. Since repeated exposures at close intervals may produce leukopenia, frequent exposure to nitrous oxide (less than one week between administrations) should be avoided.

Immunocompromised: Because N₂O seems to reduce chemotaxis (the motility of leukocytes) toward foreign proteins such as bacteria, as well as to reduce leukocyte action against tumor cells, patients with compromised immune systems should avoid nitrous oxide unless urgently required. This would include patients with AIDS or those taking immunosuppressive drugs.
Unwilling patients: \( \text{N}_2\text{O} \) should never be used on an unwilling patient. If, after explaining the benefits, the patient does not want \( \text{N}_2\text{O} \), it should not be used.

**Dental team exposure and unintended inhalation**

In a review of the advantages and harmful effects of \( \text{N}_2\text{O} \) in dental management by Ogawa and Misaki, while \( \text{N}_2\text{O} \) inhalation sedation is effective for dental treatment, leakage of \( \text{N}_2\text{O} \) in the operatory affects the health of the dental staff members. In addition to inadequate ventilation and scavenging systems, other equipment issues that may affect team members include equipment malfunctions, failures, and leaks due to poor connections. In a study by Staubli et al, vitamin B12 levels were measured in anesthetic staff applying nitrous oxide. It showed reduced vitamin B12 plasma levels by measuring homocysteine, methylmalonic acid, vitamin B12, blood count, and the MTHFR C677T genotype. The study concluded that, provided a safety demand valve is used, the use of nitrous oxide (50%-70%) is safe for the vitamin B12 status of medical personnel.

**Modes of Delivery**

There are two types of nitrous oxide/oxygen delivery systems, built-in and portable. A built-in system requires a central system with the supply source of \( \text{N}_2\text{O}-\text{O}_2 \) located in a storage area (cylinder room) separate from the treatment rooms. Flowmeters and the accessory equipment required for the delivery of the gases reside in the treatment rooms. Located in the dental office cylinder storage room, the manifold is a primary component of the nitrous oxide central system. In general, it serves to join multiple compressed-gas cylinders. One or more \( \text{N}_2\text{O} \) and \( \text{O}_2 \) cylinders may be attached to the manifold, but only one line for each gas exits the manifold. The exit lines carry the gases under low pressure (50–55 psi) to operators for \( \text{N}_2\text{O}-\text{O}_2 \) delivery. Access to \( \text{N}_2\text{O} \) and \( \text{O}_2 \) in individual treatment rooms is achieved via operatory outlets. Cylinder storage room components typically include a manifold with safety pressure relief valves, regulators for each cylinder, an alarm-monitor gauge, a cable, an \( \text{N}_2\text{O}-\text{O}_2 \) supply source (cylinders purchased from a gas supply company), tank restraints, various hoses, and gas lines. Conveniently located somewhere between the cylinder storage room and the operators plumbed for nitrous oxide is a zone valve that can be accessed in case there is reason to shut down the supply of gas immediately.

The portable unit is a self-contained delivery system. Mobility is the major advantage of the portable unit. It is usually the system of choice in offices where space limitations will not accommodate a central storage room or when economic constraints are an influencing factor. Also, the portable system is most likely the answer when frequency of \( \text{N}_2\text{O}-\text{O}_2 \) use is low. Components of the portable unit typically include a manifold with safety pressure relief valves, regulators for each cylinder, an alarm monitor gauge, an \( \text{N}_2\text{O}-\text{O}_2 \) supply source (cylinders purchased from a gas supply company), tank restraints, various hoses and gas lines. In the portable unit, the manifold, the \( \text{N}_2\text{O}-\text{O}_2 \) gas cylinders, and the flowmeter function as one unit. All components reside in the treatment room. Located on the portable unit, the manifold is a primary component of the nitrous oxide system. Two or four \( \text{N}_2\text{O} \) and \( \text{O}_2 \) gas cylinders (depending on whether the portable is a 2-cylinder or a 4-cylinder system) may be attached to the manifold, but only one line for each gas exits the manifold. The exit lines carry the gases under low pressure (50-55 psi).

**Conclusion**

Nitrous oxide is a valuable agent that assists patients who are anxious and fearful. It has an excellent safety record when used for anxiolysis and conscious sedation. There are, however, certain parameters that must be followed to ensure that every patient receives the proper and correct mode of treatment in this area.

**References**


Author Profile
Ian Shuman, DDS, MAGD, AFAAID, maintains a full-time general, reconstructive, and esthetic dental practice in Pasadena, Maryland. Since 1995, he has lectured and published on advanced, minimally invasive techniques, while teaching procedures to thousands of dentists and developing many of the methods. Dr. Shuman has published numerous articles on topics including adhesives resin dentistry and minimally invasive restorative, cosmetic, and implant dentistry. He is a fellow of the Pierre Fauchard Academy.

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Questions

1. According to the International Union of Pure and Applied Chemistry (IUPAC), Nitrous oxide is officially known as:
   a. trinitrogen toluene
   b. N2O
   c. dinitrogen monoxide
   d. nitric oxide

2. The history of nitrous oxide began with its isolation by the theologian and scientist Joseph Priestly in the year:
   a. 1776
   b. 1772
   c. 1784
   d. none of the above

3. Nitrous oxide gas is produced by heating ammonium nitrate crystals to what temperature?
   a. 100°C
   b. 150°C
   c. 200°C
   d. 250°C

4. Unlike other anesthetics, nitrous oxide produces a mild analgesic effect at what concentrations?
   a. subanesthetic
   b. supraanesthetic
   c. level 4 anesthesia
   d. a and c

5. After administration is terminated, the nitrous oxide is rapidly diffused back into the lungs along with oxygen and other gases. Due to this, oxygen exchange into the lungs and circulation is impaired, which can result in:
   a. hyperalgesia
   b. hyperbaricity
   c. diffusion hypoxia
   d. hypothermic induction

6. The use of a combination of drugs to induce relaxation and provide some analgesia during a medical or dental procedure is called:
   a. anxiolysis
   b. conscious sedation
   c. deep anesthesia
   d. none of the above

7. To reduce fear, all of the following have been used except:
   a. acupuncture
   b. pilates
   c. hypnosis
   d. acupressure

8. Asthma is not a contraindication to the use of N2O since N2O is not irritating to the:
   a. tracheobronchial tree
   b. alveolar lobes
   c. secondary bronchus only
   d. cardiac notch

9. In an article by Munson, it has been suggested that a contraindication for nitrous oxide would include any recent surgery of the:
   a. eye
   b. colon
   c. ear
   d. phalanges
10. Nitrous oxide is commonly known as all of the following except which of the following:
   a. hypernitrous oxide
   b. NOS
   c. sweet air
   d. protoxide of nitrogen

11. In the pregnant patient, the use of nitrous oxide:
   a. is absolutely contraindicated
   b. is recommended during early pregnancy
   c. may be used following consultation with the obstetrician
   d. none of the above

12. Because nitrous oxide appears to increase the effects of marijuana, a moderately “stressful” dental experience may become:
   a. traumatic
   b. euphoric
   c. diaphoretic
   d. enuretic

13. The prevention or reduction of anxiety is known as:
   a. conscious sedation
   b. inhalation sedation
   c. a and b
   d. anxiolysis

14. In the brain, nitrous oxide is a cerebral:
   a. vasoconstrictor
   b. vasodilator
   c. vaso-vagal reactor
   d. a and c

15. Repeated exposure of nitrous oxide at close intervals (less than one week between administrations) may cause:
   a. thrombocytopenia
   b. leukopenia
   c. hemophilia
   d. anemia

16. At room temperature, nitrous oxide is:
   a. colored
   b. flammable
   c. acrid
   d. sweet tasting

17. In both the United States and Canada, nitrous oxide tanks are what color:
   a. white
   b. green
   c. blue
   d. black

18. What pair of dentists were the earliest proponents of inhalation anesthetic?
   a. Priestly and Davy
   b. Wells and Morton
   c. Morton and Downy
   d. none of the above

19. To prevent any possibility of hypoxia following cessation of nitrous oxide, patients should receive:
   a. 104% oxygen for ten minutes
   b. 100% oxygen for three to five minutes
   c. a lower dose of nitrous oxide
   d. 80% helium/20% oxygen for ten minutes

20. Patients with compromised immune systems should avoid nitrous oxide unless urgently required, since nitrous oxide seems to reduce:
   a. homeostasis
   b. macrophage activity
   c. ubertaxis
   d. chemotaxis

21. Nitrous oxide is tailor made for all but what type of patient:
   a. unwilling
   b. healthy
   c. middle-aged
   d. cardioverted

22. In a study by Staubli et al, staff who administered nitrous oxide showed a reduction in plasma levels of which vitamin:
   a. B1
   b. B2
   c. B12
   d. D

23. Nitrous oxide has a solubility coefficient that is 35 times more than:
   a. nitrogen
   b. hydrogen
   c. oxygen
   d. argon

24. As an industrial gas, nitrous oxide is used:
   a. as an oxidizer in rockets
   b. in auto racing to increase engine output power
   c. as a foaming agent for whipped cream
   d. all of the above

25. Which of the following statements is true:
   a. Blocked Eustachian tubes, bowel, sinusitis and pneumothorax that allow a rapid pressure increase in a closed body cavity, leading to pain, are not contraindications in the use of N₂O.
   b. The inability to communicate with a patient is not contraindication to the use of N₂O.
   c. In a pregnant patient, if N₂O is necessary to reduce stress, it may be used following consultation with the patient’s obstetrician.
   d. N₂O is ideal as a stand alone treatment in an apprehensive patient, or as a substitute for anesthesia.

26. Which of the following usually alters cerebral cortex function:
   a. acetaminophen
   b. bystolic
   c. beta blockers
   d. psychotropic drugs

27. In many asthmatics, especially in children, the primary precipitant to an asthma attack appears to be:
   a. nasopharyngeal obstructions
   b. severe sinusitis
   c. emotional stress
   d. cognitive disturbances

28. The fast onset and quick recovery seen with nitrous oxide/oxygen sedation is due to its rapid diffusion and saturation in:
   a. central nervous system
   b. cerebral tissue
   c. blood
   d. serum

29. Which of the following pharmacological agents are used in dentistry for sedation?
   a. benzodiazepines
   b. narcotic analgesics
   c. hypnotic/amnesic agents
   d. all of the above

30. In 1800, who was the English chemist who published the history, chemistry, physiology and recreational use of nitrous oxide?
   a. Davy Jones
   b. Humphry Davy
   c. Davy Crockett
   d. Humphry Bogart
Nitrous Oxide: Use and Safety

Name: ____________________________  Title: ____________________________  Specialty: ____________________________

Address: ____________________________  E-mail: ____________________________

City: ____________________________  State: __________  ZIP: __________  Country: ____________________________

Telephone: Home ( )  Office ( )

Lic. Renewal Date: ____________________________  AGD Member ID: ____________________________

Requirements for successful completion of the course and to obtain dental continuing education credits: 1) Read the entire course. 2) Complete all information above. 3) Complete answer sheets in either pen or pencil. 4) Mark only one answer for each question. 5) A score of 70% on this test will earn you 3 CE credits. 6) Complete the Course Evaluation below. 7) Make check payable to PennWell Corp. For Questions Call 800-633-1681

If not taking online, mail completed answer sheet to

PennWell Corp.
Attn: Dental Division,
1421 S. Sheridan Rd., Tulsa, OK, 74112
or fax to: 918-831-9804

Please evaluate this course by responding to the following statements, using a scale of Excellent = 5 to Poor = 0.

Educational Objectives
1. Were the individual course objectives met? Yes  No
   Objective #1: Yes  No  Objective #2: Yes  No
   Objective #3: Yes  No  Objective #4: Yes  No

   Please evaluate this course by responding to the following statements, using a scale of Excellent = 5 to Poor = 0.

   Objective #1: Were the individual course objectives met?
   Objective #2: Understand the properties of nitrous oxide
   Objective #3: Know the safety recommendations
   Objective #4: Have the ability to deliver nitrous oxide in a safe manner and know the contraindications

   1.  Were the individual course objectives met?
      Yes  No
   2.  To what extent were the course objectives accomplished overall?
      S 4 3 2 1 0
   3.  Please rate your personal mastery of the course objectives
      S 4 3 2 1 0
   4.  How would you rate the objectives and educational methods?
      S 4 3 2 1 0
   5.  How do you rate the author's grasp of the topic?
      S 4 3 2 1 0
   6.  Please rate the instructor's effectiveness.
      S 4 3 2 1 0
   7.  Was the overall administration of the course effective?
      S 4 3 2 1 0
   8.  Please rate the usefulness and clinical applicability of this course.
      S 4 3 2 1 0
   9.  Please rate the usefulness of the supplemental webliography.
      S 4 3 2 1 0
   10. Do you feel that the references were adequate?
       Yes  No
   11. Would you participate in a similar program on a different topic?
       Yes  No
   12. If any of the continuing education questions were unclear or ambiguous, please list them.

   13. Was there any subject matter you found confusing? Please describe.

   14. How long did it take you to complete this course?

   15. What additional continuing dental education topics would you like to see?

   If paying by credit card, please complete the following:
   Acct. Number: ____________________________
   Exp. Date: ____________________________

   Charges on your statement will show up as PennWell

   1.  A  B  C  D  E
      2.  A  B  C  D  E
      3.  A  B  C  D  E
      4.  A  B  C  D  E
      5.  A  B  C  D  E
      6.  A  B  C  D  E
      7.  A  B  C  D  E
      8.  A  B  C  D  E
      9.  A  B  C  D  E
     10. A  B  C  D  E
     11. A  B  C  D  E
     12. A  B  C  D  E
     13. A  B  C  D  E
     14. A  B  C  D  E
     15. A  B  C  D  E

   AGD Code 344

PEOPLE PHOTOCOPY ANSWER SHEET FOR ADDITIONAL PARTICIPANTS.

We encourage participant feedback pertaining to all courses. Please be sure to complete the survey included
with the course. Please e-mail all questions to: toothed@pennwell.com

INSTRUCTIONS

All questions should have only one answer. Grading of this examination is done manually. Participants will
receive confirmation of passing by receipt of a verification form. Notification of Participation forms will be
mailed within two weeks after taking an examination.

COURSE EVALUATION and PARTICIPANT FEEDBACK

For IMMEDIATE results, go to www.ineedce.com to take tests online.

Payment of $59.00 is enclosed. (Checks and credit cards are accepted.)

If paying by credit card, please complete the following:
Acct. Number: ____________________________
Exp. Date: ____________________________

PennWell maintains records of your successful completion of any course for a minimum of six years. Please
contact our offices for a copy of your continuing education credits report. This report, which will list all
credits earned to date, will be generated and mailed to you within five business days of receipt.

PennWell Corporation is designated as an Approved PACE Program Provider by the Academy of General
Dentistry. The formal continuing education program of this provider is accepted by the AGD for Fellowship/ Mastership credit. Please contact PennWell for current term of acceptance. Participants are urged to contact
their state dental boards for continuing education requirements. PennWell is a California Provider. The California Provider number is 4527. The cost for courses ranges from $20.00 to $110.00.

For Questions Call 800-633-1681

Customer Service 800-633-1681

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CANCELLATION/REFUND POLICY

Any participant who is not 100% satisfied with this course can request a full refund by contacting PennWell by writing:

PennWell Corp.
Attn: Dental Division,
1421 S. Sheridan Rd., Tulsa, OK, 74112
or fax to: 918-831-9804

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IMAGE AUTHENTICATION

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Remote Flow System™ and RFS™ Chairmount Kit is a gas delivery and vacuum control system located chairside that eliminates scavenging circuit hoses draping from adjacent cabinetry. Kits are available for a wide variety of dental chair brands.

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