A Review of the Use of Inhalation Sedation in General Dental Practice

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Abstract

Within dentistry, nitrous oxide inhalation sedation is the safest form of sedation used. It is particularly useful in anxious but co-operative children. One of problems associated with the use of nitrous oxide is the occupational exposure which has been linked to decreased psychomotor performance, haematological disorders, spontaneous abortion and reduced fertility. This article reviews the history, use and safety issues surrounding occupational exposure to nitrous oxide and offers guidance on the use of nitrous oxide inhalation sedation in general dental practice.

Introduction

Since 1844 nitrous oxide (N_2O) has been widely used for sedation to manage pain and anxiety in patients. Sedation is used to calm a nervous, apprehensive patient through the use of drugs without inducing the loss of consciousness. By definition, verbal contact with the patient is maintained, their protective reflexes remain intact and the patient is able to understand and respond to verbal commands. Nitrous oxide causes mental/muscular relaxation, decreases the fear for future dental treatment and has analgesic properties. It has an excellent clinical record with few side effects and has reduced the need for general anaesthetic in the anxious patients.

Whilst a valuable tool in managing patients, chronic exposure in dental professionals has been linked to decreased psychomotor performance, spontaneous abortion, reduced fertility, malignancy and congenital abnormalities[1]. It is now legally incumbent on all organisations using nitrous oxide, to control the occupational exposure to this gas to below 100ppm over a time-weighted average (TWA) period of eight hours, under the Control of Substances Hazardous to Health (COSHH) Regulations 2002 [2,3,4].

A Brief History[5]

Joseph Priestley discovered nitrous oxide in 1776. In the early 1800s nitrous oxide was used as a recreational drug. Under the influence of the gas, individuals became excited and euphoric, lost all their inhibitions and laughed, hence the alternative name for nitrous oxide, “laughing gas”.

In 1844 Horace Wells, a dentist from Connecticut, attended a public demonstration of nitrous oxide where the gas was administered to volunteers. One of the volunteers whilst under the effects of the drug injured his leg. Wells asked him if he felt any pain and the volunteer responded that he did not until the effects of the gas wore off. It was this observation of Wells that led to him exploring the possible use of nitrous oxide in general and dental surgery. Wells is acknowledged as the founder of anaesthesia.

Wells decided to test the anaesthetic possibilities of nitrous oxide by asking his colleague to extract his decayed molar. The procedure was uneventful with Wells exclaiming that it was “a new era in tooth pulling.” Wells had benefited from the analgesic effect of nitrous oxide and stated that he was totally unaware of the procedure and had experienced no pain. Wells used nitrous oxide with great success on his patients. He was, however using 100% nitrous oxide with no oxygen which rendered his patients unconscious and hypoxic. Administrating oxygen concentrations of less than 20% can be fatal.

It was not until 1868 that Paul Bert designed an apparatus that could deliver the combination of 25% oxygen and 75% nitrous oxide. This led to the modern delivery system responsible for the remarkable safety record associated with nitrous oxide/oxygen administration.

Method of Action

Little is known about the method of action of nitrous oxide, although several theories have been proposed. The most widely accepted theory is that when N_2O is inhaled it becomes soluble in the blood stream and crosses the blood-brain barrier into the brain. It has been shown to interact with cerebral nerve membrane proteins causing the membrane to expand. This is thought to alter the binding of neurotransmitters to the nerve synapses, which leads to Central Nervous System (CNS) depression and anaesthesia. Another possible mechanism is that N_2O causes changes in membrane protein structure of neurones thereby altering ion flow and the ability to conduct impulses[6].

Occupational exposure

The regular use of nitrous oxide by dental professionals leads to chronic exposure to minute amounts of the gas. Vaisman in 1968[7] first drew attention to potential adverse effects of N_2O, by reporting problems including irritability, headache, fatigue, nausea and spontaneous abortion in Russian female anaesthesiologists. In this study of 31 pregnant female anaesthetists, only 7 births were complication free and 18 resulted in spontaneous abortion. Askrog et al showed similar problems in women who worked in operating theatres [8].

Bone marrow suppression attributed to prolonged N_2O exposure has been reported in patients receiving treatment for tetanus[9]. A study by Sweaney et al[10] found bone marrow suppression in 3 out of 20 dentists exposed to N_2O. They concluded that N_2O caused a decrease in Vitamin B_{12} activity subsequently resulting in decreased DNA synthesis. This may further result in impaired red blood cell production and the development of pernicious anaemia. However, some dentists exposed to over 5000ppm N_2O exhibited no change in bone marrow activity[10].

Animal studies have shown exposure to nitrous oxide during gestation leads to teratogenic effects, spontaneous abortion and reduced fetal weight[11]. Conversely, studies have also shown rats exposed to 0.5%, 5% and 50% N_2O for 8 hours a day during gestation had no teratogenic effects [12].

Cohen et al[13,14] conducted surveys into the effects of nitrous oxide, amongst 61,197 dentists and chairside assistants, they found a higher incidence of renal, hepatic (1.7 fold increase in liver disease) and neurological disorders in exposed dental professionals. They found a four-fold increase in neurological complaints (numbness, tingling and muscle weakness) in exposed dental professionals compared to the unexposed. There was also an increase in spontaneous abortions and congenital abnormalities in chairside assistants and the dentists' wives. They found a 2.3 fold increase in spontaneous abortion among female chairside assistants who were exposed to N_2O. They also found a 1.5 fold increase in spontaneous abortion among the wives of exposed dentists compared to the wives of non-exposed dentists. The results of these studies must be considered with the knowledge that some respondents were exposed to other anaesthetic gases in addition to N_2O and no attempt was made to identify recreational N_2O users.

Rowland et al[15] investigated pregnancy in dental nurses. They monitored different groups of assistants with different levels of exposure to N_2O and recorded if a scavenging system was used. They found only those nurses exposed to nitrous oxide with high usage and without scavenging systems displayed a statistically significant decrease in the ability to conceive. For each hour of exposure to unscavenged nitrous oxide, they found fertility to be reduced by 6%. Women who were exposed to unscavenged N_2O for 5 or more hours a week were only 41% as likely to get pregnant compared to their unexposed counterparts. In a further study it was reported that women who worked with unscavenged N_2O for 3 hours or more a week had a 2.5 fold increase in their rate of spontaneous abortion. Therefore, female dental assistants were at a decreased risk of spontaneous abortion when N_2O scavenging equipment was used compared to when not used[16].

It has been suggested that the means by which chronic exposure affects fertility is mediated centrally. In rats, nitrous oxide has be shown to interfere with the hypothalamic-pituitary-gonadal axis by decreasing the release of luteinising hormone releasing hormone (LHRH) from the hypothalamus[17].

Conversely, studies that have investigated the incidence of spontaneous abortion in hospital theatre nursing staff found no link with exposure to anaesthetic gases[18,19].

It must be noted that many of the studies above are dated and do not stand up to rigorous analysis, with confounding factors often not taken into account. However, the weight of evidence indicates there are detrimental effects from chronic occupational exposure to increased levels of nitrous oxide and it is thus important to reduce levels to a minimum. It would also seem prudent, that if a member of staff is trying to become pregnant or is pregnant, then that member of staff should cease working with N_2O until the baby is born.

Risk Assessment

The need to produce a risk assessment into the use of nitrous oxide in regards to occupational exposure is a legal requirement of COSHH regulations 2002[2,3,4]. This includes, when and where it is being used and monitoring the levels produced. N_2O leaks may arise anywhere along the apparatus, from connectors or tubing connecting parts of the apparatus to the scavenging masks. Risk assessment will help identify sources of excess production and enable reducing measures to be instigated. Such monitoring should include; Leak testing of equipment, monitoring of air in the workers' personal space and room air monitoring. The monitoring must be maintained on a periodic basis, as recommended by the N_2O delivery, scavenging and monitoring equipment manufacturers. Regular equipment maintenance by reputable organisations is essential to reduce N_2O exposure. These inspections should be accompanied by a written report, detailing work carried out, any recommendations for further work and a due date for the next inspection. Specific training for staff using nitrous oxide is essential in order to use the equipment correctly and minimise occupational exposure.

Scavenging Systems

Scavenging systems are usually connected to the N_2O nasal delivery device with the purpose of removing excess gas (exhaled or escaping from the mask). With the risk of chronic exposure in mind the Health Services Advisory Committee (HSAC) 1995 recommended a TWA during exposure of below 100ppm for dental staff over an eight hour period[20]. TWA is an average exposure during use of inhalation sedation, normally calculated by summing the N_2O readings and dividing it by the number of minutes in use. The National Institute for Occupational Safety and Health (NIOSH) USA 1994 recommended TWA exposure of below 50ppm[21]. In France and

Denmark the recommended levels are 25ppm[22]. The difference is due to the unknown safe dose of N_2O. Only effective scavenging can keep the doses below these levels[23]. Indeed, without scavenging systems in place levels of N_2O up to 7000ppm have been recorded in practice[24].

Few studies have compared the efficiencies of different scavenging systems. Studies are limited by the number of variables involved when recording nitrous oxide levels, for example, respiratory rates, patient behaviour (talking, crying), mouth or nose breathing, nitrous oxide levels delivered, recording times, distance to N_2O monitor, N_2O monitor, surgery size, surgery air exchange rate, operator technique and variation in the fit of nasal masks, make studies very difficult to standardise.

Borganelli et al[25] conducted a study into operatory ventilation and found operatory ventilation and scavenger evacuation rates had an inverse relationship to ambient nitrous oxide levels in a closed surgery. The study showed that levels of N_2O could be reduced below 25ppm when air exchange rates were over 10 per hour.

A study by Henderson and Matthews 2000[26] monitoring N_2O levels in dental operating theatres and a dental community clinic without scavenging systems found levels higher than recommended limits on certain occasions and concluded the need for scavenging systems to keep levels within these limits. Girdler and Sterling[22] found active scavenging with an active waste gas scavenging system kept N_2O below 50ppm (TWA) in a dental hospital sedation department. Dunning et al study[27] sent out N_2O monitors to 70 dental practices in the USA and monitored their N_2O exposure. They found an average Dentist exposure of 97ppm (40 hr week TWA), recording peaks of exposure of 1415ppm. There were many variables in their study including operator variations, surgery differences, technique variation, use of scavenging and recording errors amongst others. Thus, it was hard to conclude any best practice guidelines from their study.

Benefits of Nitrous Oxide Use

Inhalation sedation with nitrous oxide has an excellent safety record in patients with no reports of any allergies, fatalities or cases of serious morbidity related to the technique[28]. Lyratzopoulos and Blain's 2003[29] review found morbidity associated with inhalation sedation is minor and infrequent, and user satisfaction is high, or higher compared with dental general anaesthetic (DGA). However, comparing with DGA, inhalation sedation requires significantly longer time per episode and more treatment sessions per patient. In teaching dental hospitals, staffing costs for inhalation sedation are estimated to be cheaper by about a third compared with outpatient DGA. They concluded 45-64% of all children referred in for DGA maybe treatable under inhalation sedation. Inhalation sedation with nitrous oxide is particularly beneficial compared with DGA for medically compromised patients. Patients with cardiovascular disease and cerebrovascular disease, benefit from the increased concentrations of oxygen administrated, as part of the technique. Patients with bleeding disorders, sickle-cell trait, sickle-cell disease, epilepsy, liver and kidney disorders, diabetes and bronchial asthma can all benefit from the technique[28].

Contraindications

Few relative contraindications exist. Practitioners should use caution if patients present with a common cold (a patent nasal airway is required), chronic obstructive pulmonary disease (e.g. emphysema or chronic bronchitis), severe asthma, otitis media, psychiatric disorders or in the first trimester of pregnancy. Under these circumstances it is best practice to consult the patient's general practitioner or hospital physician or alternatively refer in to a hospital based specialist[28].

Administration of Nitrous Oxide[30,31]

This essentially involves having a co-operative, understanding and relaxed patient. The technique of inhalation sedation strongly relies on the dentist's participation and relaxation of the patient. Acceptance and depth of sedation is enhanced if a semi-hypnotic suggestion with a calm, monotonous voice is used. Continued communication with the patient is essential. It is therefore sometimes seen as hypnosedation.

Pre- and postoperative instructions should be given before treatment to both the patient and escort and consent should be obtained for each episode of sedation and treatment.

It is important to follow manufacturer guidelines on daily and pre-operative equipment checks. On the day of the appointment, the pressure gauges of the cylinders should be checked for quantity. The gas cylinder valves should be fully opened and checked for leaks.

The reservoir bag should be checked by blocking the tubing while both gaseous valves (nitrous oxide and oxygen) are open and then squeezing the bag and checking for positive pressure against the blocked tubing. Finally, the safety mechanism should be checked by turning off the oxygen cylinder whilst both gases are flowing and confirming the nitrous oxide also cuts off.

A close fitting nasal mask should be selected. 100% oxygen is then delivered in accordance to the patient's tidal volume (4l/min for children and 6-8l/min for adults). 10% nitrous oxide is administered for a minute. Verbal reassurance from the dentist is continued throughout the procedure. The concentration of nitrous oxide is then increased by 10% for a further minute and then in increments of 5% until the patient appears and feels quite relaxed. The final amount of nitrous oxide is titrated according to patient response, it normally lies within the range of 30-50% N_2O (to a maximum of 70% N_2O/30% O_2). Mouth props should not be used, as the ability to maintain mouth opening is an important clinical indicator of the level of sedation.

Patient assessment and baseline monitoring should be carried out throughout the procedure. This includes, monitoring patient verbal responses, skin colour, heart rate and number and quality of respirations. A lack of patient response to verbal commands at any stage, should instigate the termination of treatment immediately, with 100% O_2 delivered and the patient re-evaluated.

To ensure a smooth and safe recovery phase, the patient receives 100% oxygen for approximately 3 minutes before removing the mask. This step is important to avoid diffusion hypoxia, which may result due to the rapid release of N_2O from the bloodstream into the alveoli, diluting the concentration of oxygen. The patient should then be allowed to sit in the dental chair for a further 5 minutes before leaving with an appropriate escort and issued with written and verbal post-operative instructions.

Safe Practice

The HSAC[20] and SAAD[31] together with NIOSH[32] recommend a similar protocol to reduce occupational exposure to nitrous oxide in the dental surgery. This includes:

1. Monitoring N_2O exposure levels with suitable monitors, within the surgery.
2. Engineering controls; addressing nitrous oxide leaks and ensuring correct function of the scavenging system with N_2O monitors.
3. Scavenging systems should have a evacuation rate of at least 80ltr/min[33] (at the wall), removed outside the building, above roof level.
4. Ventilation; room ventilation should be assessed to ensure adequate air exchange (over 10/hour). Windows should be opened. Fans and/or air conditioning can be used to direct exhaled nitrous oxide away from the dental staff and improve air flow.
5. Work practices; Inspect all connections before starting. Turn on nitrous oxide only when the scavenging unit is operational. A correctly fitting nasal mask which provides a good seal, should be selected. Breathing systems should have a separate inspiratory and expiratory limb to allow proper scavenging. Operating times should be kept short and several inhalation sedation cases in one session should be avoided. Maximise patient inhalation of nitrous oxide by minimising patient

conversation and mouth breathing. Use high volume aspiration during treatment to reduce occupational exposure to nitrous oxide. Flush system with oxygen for 2 mins after use.

6. Check the equipment daily/pre-use; Inspect connectors and test for leaks with appropriate monitors regularly.
7. Maintenance; The system should be serviced according to manufacturer's recommendations. Establish a schedule for periodic inspection, which should be documented.

Interestingly, a survey conducted by Dunning et al[27] of 809 dentists showed that compliance to these guidelines in the US was poor (9 on a scale of 17). Indeed, most nitrous oxide users had scavenging systems but these were not properly operated. Further, few dental practices checked for leaks (30%) or monitored environmental N_2O levels.

Summary

Nitrous oxide has an excellent safety record in patients and is a preferable alternative to general anaesthesia for dental procedures in specific patient groups. In view of the morbidity which may be associated with chronic exposure to nitrous oxide, appropriate measures should be taken to reduce the occupational exposure. Clinical training of staff, maintenance of equipment, pre-operatory checks, appropriate patient selection and an efficient scavenging system are all important steps in minimising occupational exposure to nitrous oxide.

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