# MEASUREMENT OF WASTE GAS CONTAMINATION DURING NITROUS OXIDE SEDATION IN A NON-VENTILATED DENTAL OPERATORY

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## Introduction

Chronic exposure to waste gas in ambient air has been cited as a potential health hazard.[1] Statistically significant increases in rates of spontaneous abortion, congenital anomalies, cancer, renal and hepatic disease (excluding serum hepatitis) have been reported among personnel chronically exposed to trace concentrations of anesthetic gases.[2,4]

Although exposure to radiation and transmissable viruses have been suggested as other possible causes for the increased evidence of miscarriages among female operating room personnel, chronic low dose exposure to inhalation anesthesia has been shown to cause birth defects in laboratory animals.[5,6] Further, the survey by the American Society of Anesthesiology Ad Hoc Committee indicates that disease rates are apparently dose related in that the more heavily exposed groups, such as anesthetists, generally show a higher incidence of disease than less exposed personnel such as operating room nurses and technicians.

It has been shown that unscavenged ambient air in a typical hospital operating room contains $N_20$ in the range of 600ppm, and an average of 1000 to 3000ppm in the area of the anesthesiologist.[9]

Since dental patients are usually not intubated and because waste gas is rarely scavenged it is possible that dentists and their staffs may be exposed to even greater concentrations than operating room personnel and therefore be at an even greater risk.

Trieger and collegues have demonstrated that $N_20$ significantly impaired coordination and psychomotor function when inhaled in 25, 50 and 70 percent concentrations with $0_2$.[9] These effects have been confirmed by Ayer and Getter[10] in a study using 35-40% nitrous oxide with oxygen. Jastak and Orendurff[11] showed that a mean concentration of 41% nitrous oxide with oxygen significantly decreased performance of a psychomotor breaking test while Bruce and co-workers[12] demonstrated a significantly lower performance on a digit span test in subjects exposed to 500ppm of $N_20$ with air. Recently it has been suggested that the nitrous oxide concentration in a dental operatory after 60 minutes approaches 6000ppm.[13]

Unfortunately, in spite of the concern which exists over the potential hazards of anesthetic gases in dental operatories (particularly because of the widespread use of nitrous oxide analgesia) published reports on the subject are meager. The existing information also appears to have neglected certain important variables and their combined effects on gas concentration.

The purpose of this study was to determine the concentration of nitrous oxide in the ambient air during the administration of nitrous oxide-oxygen analgesia as a function of angle, time and distance. These important variables may determine the relative degree of risk to which the dentist is exposed.

## Materials and Methods

The participants in the research were two male and two female subjects who individually received nitrous oxide-oxygen

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analgesia during the testing sessions. The participants ranged in age from 19-20 years and in weight from 110-120 lbs. All air sampling tests were conducted in a single dental operatory.

The room was approximately 10 ft. by 11 ft. and contained standard dental cabinetry and equipment. Although the exhaust system was not operated, a duct was present at ceiling level. Aside from those leakage spaces of the door and exhaust duct, the test operatory was considered non-ventilated. Temperature and humidity were within working limits.

A Quantiflex MDM 50 nitrous oxide sedation unit was used. The $N_2O$ and $O_2$ were supplied from D size tanks connected at the head. The gas was delivered through a nonrebreathing nosepiece with one-way escape valve. (Respiratory inspirations could not draw in room air through the valve but waste gas expiration was unimpeded).

The nitrous oxide concentration was measured using a Wilks, Miran 101 Specific Vapor Analyzer which was placed on a movable cart near the investigator. A five foot long sampling hose was connected to the intake port on the machine. This exhaust port was fitted with a similar hose which carried sampled gas under the vinyl divider and out of the room.

The analyzer was capable of operating on 110 volt AC or on internal battery power. For the sake of uniformity, the unit was maintained on 110 volt AC current through the tests.

Nitrous oxide concentration is monitored continuously while the unit is in operation and records gas concentration in parts per million from 0 to 1000ppm on the lower scale in increments of 50ppm from 1000 to 6000ppm on the upper scale in increments of 250ppm.

**Procedure**

The participant was seated in the dental chair in a semi-reclining position. The nosemask was fitted snugly on the face in such a way that the valve directed the waste gas forward; in line with the subject's body and parallel to the floor. The participant was instructed to keep the mouth closed at all times and to breathe only through the nosepiece.

Before any vapor monitoring was conducted the analyzer was removed to an area approximately 50 feet from the test operatory. There, using internal battery power, it was standardized to zero and returned to the sampling room where it was connected with a 110 volt source. Readings for zero time were then taken.

Nitrous oxide concentration was set at 30% on the Quantiflex machine and a flow rate of 6 liters per minute was established. Each nitrous oxide sample was collected at the designated site for 30 seconds. Four sets of ten tests were conducted. In each set, air samples were taken at one fixed distance along each of three separate paths over four time intervals. Each path represented a vector or direct line from the valve opening at a specified angle.

The first set consisted of samples taken within one inch from the nose piece escape valve at 0°, 90° and 180° angle from straight forward dissemination at 5, 15, 30 and 45 minute intervals.

The second set consisted of samples taken at 1 foot from the valve along the 0°, 90° and 180° vectors at the same time intervals as in the first set. Samplings in the third and fourth sets were conducted for the 3 foot and 5 foot distances in the same manner as in the first and second sets.

Throughout the study consistency of angle and distance were insured by using permanently marked monitoring points.

**Results and Discussion**

In this study the concentration of nitrous oxide in the ambient air during administration of $N_2O$-$O_2$ analgesia was found to be dependent on the distance and angle from the escape valve opening as well as upon the duration of gas dissemination. The highest readings were recorded along the 0° angle (directly in front of the escape valve opening). These findings are shown in Table 1.

The data were subjected to a statistical analysis using a mixed analysis of variance with repeated measures. The results of the analysis showed the differences were highly significant ($F=8935$; $df=2/423$ $p< .001$). Post hoc comparisons (Scheffe's test) revealed that concentrations at 0° angle differed significantly from those at 90° and

100° angulations. The concentrations at 90° and 180° however did not differ significantly from each other.

Of the three parameters investigated, the angle from the direct line of dissemination was found to have the most demonstrable effect on the waste gas concentration.

At the five foot distance the influence of angulation was less pronounced. However, the mean gas concentration at each time period for the 0° vector was on the average 687ppm higher than the concentration at the same time along the 90° and 180° vectors.

When distance is considered alone as a factor responsible for $N_20$ concentration the clearest relationship can be drawn along the 0° vector, where concentrations decreased dramatically with increasing distance.

The results are more complex along the 90° and 180° vectors. Through the 5, 15, and 30 min time periods the gas concentration decreased with increasing distance at the 45 minute period showed a higher $N_20$ concentration with an increase in distance. As can be seen from Table 1, samples taken along the 90° and 180° vectors show both increasing and decreasing $N_20$ concenrations with increasing distance depending upon the duration of gas flow.

If the parameter of time is considered alone, it can be observed that at any distance $N_20$ concentration increased with time.

The pilot tests for this project indicated that many factors were responsible for the concentration of waste gas at any point and time in the dental operatory. Three of these factors were singled out for study the others were excluded or their potential to cause variation minimized.

Subjects of uniform stature were chosen since the frequency, force, and depth of their respirations were critical to the dissemination of waste gas.

The rate of concentration of $N_20$ delivery was also an important consideration. A concentration of 30% $N_20$ was used since it could be initiated from time zero and because it was well tolerated by subjects who were not allowed to regulate inspired $0_2$ concentration by mouth breathing. This control, simulated procedures in which the rubber dam is utilized and also eliminated variation in the source of waste gas.

Using subjects of uniform stature also made it possible to standardize the flow rate of 6 1/min. while neither collapsing nor overextending the reservoir bag. This was important, because when the bag was distended $N_20$ concentration at the escape vent over the bag registered almost 6000 ppm. Although of low force, this $N_20$ spillover produced a concentration of 220-250 ppm at a distance of 1 foot after 5 minutes.

Using a flow of 6 1/min. and achieving normal fluctuation in bag distension, the concentration of gas within 1 inch of the machine vent registered 1000ppm, but at 1 foot after 5 minutes (through 360°) a concentration of less than 75ppm was monitored.

Before each trial, the nosepiece was positioned snugly on the face and all hose and machine connections were secured. (In the pilot tests, leakage of $N_20$ at the tank, regulator and control head connections were common and generated local concentrations in the 600 ppm range).

The room was chosen because it approximated conditions existing in a standard dental operatory. Gas concentrations at any point in the room were greatly affected by air circulation and exchange. For this reason, to maintain a standard environment, the ventilation and exhaust systems were not used and sampling movements were kept slow and to a minimum. Air exchange through the louvered door was not controlled.

The data collected along the 0° vector projects a very understandable phenomena of increasing $N_20$ concentration with decreasing distance from the valve and increasing $N_20$ concentration with increasing duration of gas flow. However, there is a complex and apparent paradox in the data collected along the 90° and 180° vectors where the $N_20$ concentration showed both increasing and decreasing values with increases in distance. The situation is most likely explained by the rebound dissemination of gas off operatory walls, movements of the investigator during sampling, or the presence of subtle and indigenous room air exchange.

## Clinical Significance

Recommendations based on data from this study must be tempered by the uniqueness of individual operatory environments and practical clinical applicability.

Since the highest concentrations of waste gas were found along the direct line of dissemination, the opening of the nosepiece valve should be directed away from the dentist and the assistant. If this procedure is followed and direct line dissemination is through the 6 o'clock position, waste gas concentrations in the 9 o'clock, and 3 o'clock positions can be expected to be significantly less than in the areas directly over the patient.

Waste gas dissemination is not the only source of $N_20$ in ambient air. High flow rates which cause maximum bag distension create high gas flow through the machine escape vent and cause high $N_20$ concentrations near the machine. For this reason flow rate delivery of $N_20/0_2$ should be tailored to the depth and frequency of the patients respirations. The reservoir bag should not be allowed to distend maximally but neither should its complete collapse restrict inspiration.

In this study, the concentration of $N_20$ was standardized at 30%. It can be assumed however, that the delivery of greater concentrations of $N_20$ will cause a more rapid build-up of waste gas in the ambient air. Therefore, as with the gas flow rate, the concentration of delivered $N_20$ must be tailored to the patients needs. Using high concentrations which require dilution via patient mouthbreathing, cause a needless increase in room air pollution.

Faulty tank and hose connections can also be responsible for high $N_20$ concentrations near the analgesia machine. For this reason, a thorough inspections of the unit should be conducted before each use.

The escape of $N_20$ from the vent on the reservoir bag as well as from any insecure connections makes it advisable to position the machine near an exhaust duct or as far away from the operating team as is practical.

## Summary

The concentration of waste gas in the ambient air during administration of $N_20/0_2$ analgesia is dependent upon many factors. Three of these; distance from the nosepiece escape valve, position in relation to the direct line of waste gas dissemination and the deviation of the analgesia were studied.

Analysis of the data indicates that all three factors were significant in affecting gas concentration at any given point. Angulation or position in relation to the direction of waste gas dissemination was shown to be the most dominant factor. However, no single factor or pair of factors could explain the concentration as well as all three factors taken together.

**TABLE 1**

Mean values of $N_20$ concentration according to angle, distance, and time in ppm.

| ANGLE | DISTANCE | TIME 1 | Time 2 | Time 3 | Time 4 |
|---|---|---|---|---|---|
| 0° | 1 inch | 5000 | 6000 | 6000 | 6000 |
| | 1 ft. | 5850 | 6000 | 6000 | 6000 |
| | 2 ft. | 2450 | 3625 | 5550 | 5600 |
| | 5 ft. | 850 | 1225 | 1475 | 1800 |
| 90° | 1 inch | 925 | 1230 | 1300 | 1520 |
| | 1 ft. | 380 | 900 | 1180 | 1600 |
| | 2 ft. | 270 | 580 | 1100 | 1575 |
| | 5 ft. | 250 | 520 | 910 | 1130 |
| 180° | 1 inch | 800 | 980 | 1120 | 1320 |
| | 1 ft. | 370 | 680 | 1160 | 1520 |
| | 2 ft. | 220 | 650 | 1180 | 1340 |
| | 5 ft. | 290 | 710 | 900 | 1080 |

*References Continued on Page 42*

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