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A New Technique of Scavenging Exhaled Nitrous Oxide

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Sedative–hypnotics are frequently used to provide patient comfort and augment the analgesia of a regional anesthetic. Nitrous oxide is particularly valuable for such sedation due to its predictability and rapid elimination. A concentration of 50% N_2O applied through nasal prongs enhances the sedation of modest doses of parenterally administered analgesics.[1] This N_2O-based sedation provides gentle sleep with minimal postsedation intoxication. However, without a means of scavenging exhaled N_2O, significant pollution of the operating room occurs. Therefore, an effective, inexpensive, and comfortable means of scavenging exhaled N_2O is described.

METHODS

This study was conducted on 20 nonpremedicated adult patients who were to receive regional or local anesthesia for surgical procedures. Patient entry into the study was not restricted on the basis of age, sex, or physical status. All studies were approved by our Institutional Research Committees.

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On arrival in the operating room and after placement of ECG electrodes and blood pressure cuff, each patient was given iv doses of droperidol (1.25 mg) as an antiemetic; nalbuphine (10–20 mg/70 kg) as an analgesic; and low doses of diazepam (0–5 mg) as needed for sedation. The regional or local anesthetic was then performed and the patient positioned in the supine position for surgery. Nitrous oxide, 50% in oxygen, was introduced through nasal prongs at a 4 l/min flow rate. The ambient air N_2O level was continuously determined with an infrared spectrophotometer at a point within the anesthetist's breathing zone (approximately 0.5 m from the patient's nose and level with the operating table). At St. Vincent Hospital and Medical Center, a Foregger 410® N_2O monitor (Puritan-Bennett Corp., Kansas City, MO) with continuous strip-chart recording of the measured N_2O level was used. At Maricopa Medical Center, an Ohio Trace Gas Analyzer for N_2O® (Ohio Medical Products, Madison, WI) was employed, with observations recorded every 5 min. Scavenging of the exhaled N_2O was achieved by the placement of a Hudson® soft-vinyl, disposable face tent (Hudson Oxygen Therapy Sales Company, Temecula, CA) securely under and against the patient's chin. A length of disposable suction tubing connected to the regulated central vacuum source was attached to the face tent *via* a 9 mm, 90% angled, metal endotracheal tube connector. Vacuum flows of between 10–30 l/min (corresponding to suction pressures of 100–200 mmHg) were then applied and the effect on ambient air N_2O levels determined.

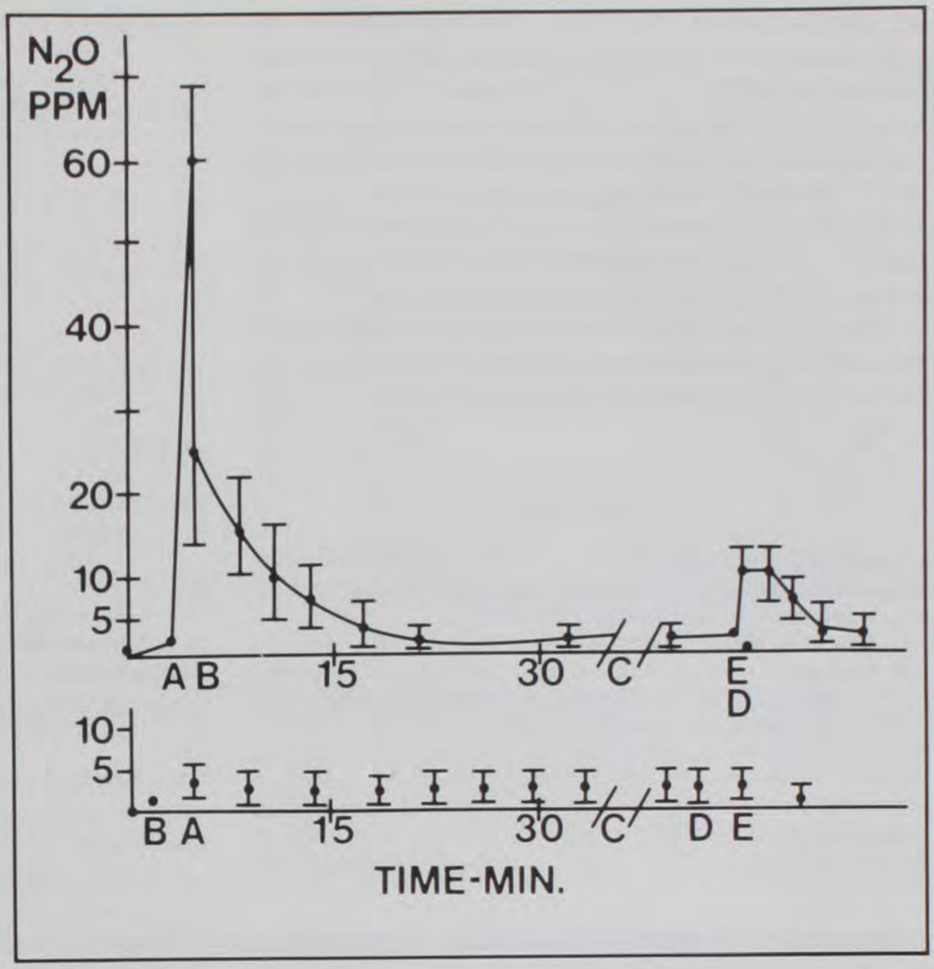

FIG. 1. Ambient levels of N_2O (ppm) in 20 patients. *Upper graph:* ten patients, with range of observations. *A* = N_2O flow started. *B* = face tent placed. *C* = variable time interval. *D* = N_2O flow stopped. *E* = face tent removed. Note N_2O increases before scavenging (*B*) and when scavenging stopped before all N_2O exhaled (*D, E*). *Lower graph:* ten patients with range of observations. N_2O levels all below 5 ppm when scavenging started (*B*), before N_2O flow (*A*), and when continued (*E*) for 3 min after N_2O flow stopped (*D*).

RESULTS

Without face mask scavenging, ambient air N_2O levels quickly rose to 40–70 ppm (peak 53 ppm ± 25 ppm SD), depending on the efficacy of the nonrecirculating air conditioning system (fig. 1, *upper graph, point B*). Within 3 min of initiation of face mask scavenging, N_2O levels declined to a level below 25 ppm in all patients tested. Nitrous oxide levels consistently below 4 ppm required 10–15 min of equilibration. Variation in the vacuum flow rates did not significantly alter the N_2O spillage rate.

To maximize the effectiveness of face–tent scavenging, the tent was applied and vacuum scavenging initiated prior to the introduction of N_2O through the nasal prongs. When this procedure was followed (fig. 1, *lower graph, point B*), environmental N_2O levels never exceeded 5 ppm.

When, at the end of the case, the face mask scavenger was removed and the N_2O flow discontinued at the same time, significant N_2O spillage (range 10–50 ppm) reappeared as residual alveolar N_2O was exhaled (fig. 1, *upper graph, points D and E*). When face mask scavenging was continued, however, for 1–2 min beyond the cessation of N_2O flow, (fig. 1, *lower graph, points D and E*), no excess N_2O was detected.

DISCUSSION

Nitrous oxide, when used as the primary sedative during regional anesthesia, is a useful alternative to diazepam and/or opioid sedation. It is predictable, effective, rapidly reversible, and easy to administer.[2] Postoperative diazepam intoxication and opioid-induced respiratory depression are avoided.[3,4] However, a number of studies have suggested (but never conclusively established) that chronic exposure to unscavenged N_2O could have adverse effects on reproductive potential,[5,6] bone-marrow[7] and neurologic[8] function, and vitamin B_{12}-dependent cellular mechanisms.[9]

Whether or not such toxicities have clinical and practical significance,[10,11] it is incumbent on practitioners to minimize undue exposure to potentially harmful agents. To this end, we have described a highly effective technique for scavenging exhaled nitrous oxide when it is used as an adjunctive agent during regional anesthesia. Levels well below the current trace-gas target level§ of 25 ppm

§ National Institute of Occupational Safety and Health criteria for a recommended standard-Occupational exposure to waste anesthetic gases and vapors. Department of Health, Education, and Welfare (NIOSH) publication no. 77–100, 1977.

are easily achieved. We believe this represents an improvement over scavenging techniques using a face mask because the latter: 1) require a cumbersome circle circuit; 2) depend on a tight mask fit to prevent spillage; and 3) are often associated with considerable patient discomfort due to sweating under the mask and a feeling of claustrophobia. The presently described apparatus consists of materials that are inexpensive, reusable, and readily obtained. Nitrous oxide-based sedation can, therefore, be an effective alternative to heavy diazepam and/or opioid sedation for regional or local anesthesia without exposing operating room personnel to excessive levels of nitrous oxide.

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Intravenous Regional Anesthesia: Evaluation and Prevention of Leakage under the Tourniquet

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Intravenous regional anesthesia has been associated with at least seven deaths,[1] two cardiopulmonary arrests,[2,¶] ten generalized seizures,[3–6] and many milder toxic symptoms.[7,8] Unintentional leakage of injected anesthetic solution under the tourniquet seems to have been an important factor in many of these cases. Many investigators,[2–4,9,10] using a variety of techniques, have found that injected solution can leak past a correctly inflated tourniquet. Radiocontrast studies[2,4,9] provide clear evidence that such leakage occurs primarily *via* the venous system, thereby demonstrating that venous pressures during injection can equal or exceed the effective tourniquet pressure.

The effective tourniquet pressure is that pressure transmitted to the underlying arteries and veins of the arm. The main factor relating effective tourniquet pressure to the registered (gauge) tourniquet pressure is the width of the tourniquet in relation to the size of the limb. For the effective tourniquet pressure to equal the registered tourniquet pressure, the cuff width should be approximately 20% wider than the diameter of the limb. Accordingly, the American Heart Association recommends that sphygmomanometer cuffs for adult blood pressure measurements should be 12–14 cm wide.[11] Double tourniquets are advantageous and commonly used during intravenous regional anesthesia, but by anatomic necessity each tourniquet can be only 5–6 cm wide. Consequently, the effective tourniquet pressure with narrow

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