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Negative Middle Ear Pressure and Postoperative Vomiting in Pediatric Outpatients

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Nitrous oxide anesthesia may cause a higher incidence of postoperative nausea and vomiting than anesthesia without nitrous oxide.[1,2] The mechanism of this proposed effect may be related to negative middle ear pressure during recovery, stimulating the vestibular system by placing traction on the round window membrane.[3] During 70% nitrous oxide administration, there is a rapid rise in middle ear pressure of approximately 1.0–2.0 cm H_2O/min^{-1}. Passive venting *via* the eustachian tube occurs at 20.0–30.0 cm H_2O.[3,4] Negative middle ear pressures occur in the postoperative period as the nitrous oxide diffuses out rapidly. The relatively compliant walls of the eustachian tube tend to collapse and do not permit re-equilibration with atmospheric pressure.[5] This study was designed to assess the relationship between postoperative middle ear pressure after nitrous oxide and halothane anesthesia and vomiting in pediatric outpatients.

MATERIALS AND METHODS

With institutional approval and informed consent, 60 children, ASA physical class 1 or 2, aged 3–18 yr, were studied. Those with diseases known to increase vomiting or to contraindicate the use of nitrous oxide were excluded. Procedures on the middle ear, tonsillectomy and adenoidectomy, and ocular surgery were thus excluded. Patients with known middle ear dysfunction

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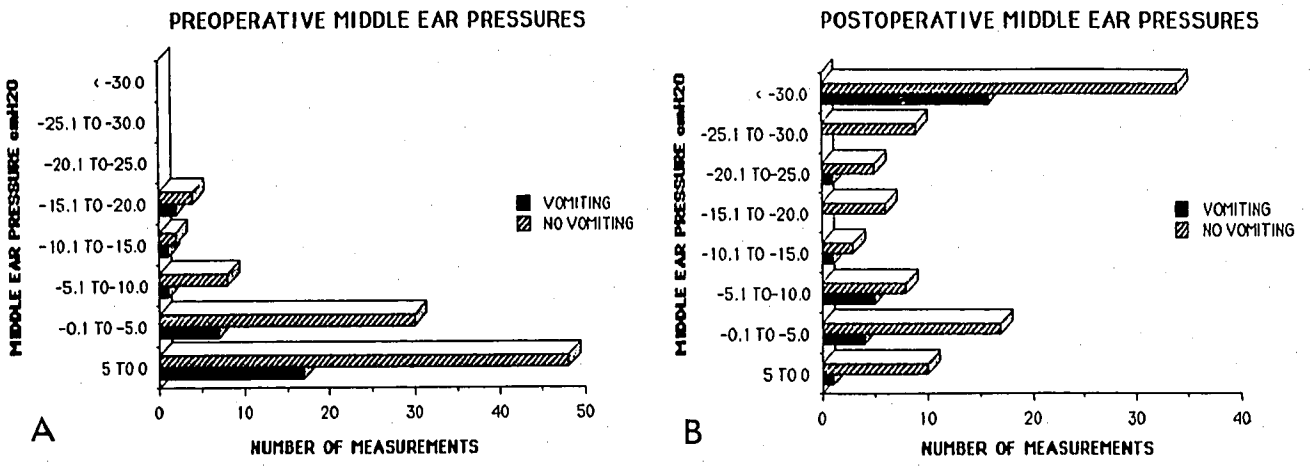

FIG. 1. The distribution of middle ear pressure (cm H_2O) preoperatively and postoperatively in vomiting and non-vomiting patients. *A.* Preoperative middle ear pressures. *B.* Postoperative middle ear pressures.

were also excluded. Patients were assessed for a history of recent upper respiratory tract infection by questioning as to whether there had been any cough or rhinorrhea within the last week. All were day care patients undergoing peripheral surgery.

Bilateral measurements of middle ear pressure were performed pre- and postoperatively using impedance typanography with a Madsen Electronics® 29330 Impedance Audiometer, as previously described.[5] Any patients with abnormal baseline tympanograms (without a clearly defined peak) were then excluded from the study. No premedication was given. Anesthesia was induced with thiopental 4–6 $mg \cdot kg^{-1}$ and atropine 0.02 $mg \cdot kg^{-1}$ iv, and maintained with 70% nitrous oxide in oxygen and halothane (1–3%). Endotracheal intubation was performed, if indicated, with the aid of succinylcholine 1.0–2.0 $mg \cdot kg^{-1}$ iv. The duration of anesthesia with nitrous oxide was at least 15 min. No prophylactic antiemetic drugs were used. Postoperative analgesia was obtained with regional nerve blocks, local anesthetic infiltration, acetominophen 10–15 $mg \cdot kg^{-1}$, or codeine 1–1.5 $mg \cdot kg^{-1}$ orally.

Vomiting observed during the recovery room and daycare unit stay (early vomiting) and during the ensuing 24 h (late vomiting) was documented by the nursing staff and by a parent telephone interview. Patient followup was 100%. The time from discontinuation of nitrous oxide to the first oral intake and the total recovery time (defined as the time from discontinuation of anesthetic gases to the time of discharge) were recorded. Postoperative middle ear pressures were recorded prior to discharge, and the time elapsed from discontinuation of nitrous oxide was noted. Abnormal postoperative ear pressure was defined as a deviation of greater than 5.0 cm H_2O from baseline measurement.[5]

Statistical analysis was performed using the Mann-Whitney U test to compare age, weight, duration of nitrous oxide exposure, time to oral intake, total recovery time, and time to middle ear pressure measurement in vomiting and non-vomiting patients. Contingency table analyses with Yates modification, where appropriate, were performed to compare the incidence of vomiting and abnormal ear pressure, >8 yr of age and ≤8 yr of age, use of endotracheal intubation, type of surgery, and the use of codeine. Analyses also compared abnormal ear pressure *versus* age and recent upper respiratory tract infection. P values of <0.05 were considered significant.

RESULTS

A total of 60 patients, 17 boys and 43 girls, were studied. The pre- and postoperative middle ear pressures recorded in vomiting and nonvomiting patients are shown in figure 1. The majority of surgical procedures studied were dental (table 1).

Vomiting occurred in 14 of 60 patients (23%). Five patients vomited while in hospital, early vomiting (8%); and nine vomited only in the ensuing 24 h, late vomiting (15%). Three of the five early vomiting patients also vomited at home. The duration of nitrous oxide exposure was significantly longer in the vomiting group. Comparison of other data between patients who vomited and those who did not revealed no difference in

TABLE 1. Types of Surgical Procedures

Type	Number
Dental	41
Orthopedics	8
General	5
Urology	3
Plastics	3

TABLE 2. Comparison of Vomiting and Non-vomiting Patients

	Vomiting (n = 14)	Non-vomiting (n = 46)
Age (years)	9.6 ± 5.0	10.7 ± 4.8
Weight (kg)	36.5 ± 17.8	36.0 ± 17.8
Duration of N_2O (min)†	74.2 ± 43.5	42.5 ± 32.3*
Time to P.O. (min)‡	95.0 ± 64.7	86.2 ± 26.4
Time to ear pressure measurement (min)§	143.5 ± 37.9	121.6 ± 26.4
Total recovery time (min)¶	152.6 ± 34.3	139.7 ± 27.1

* Denotes statistical significance ($P < 0.01$) (mean ± SD).
† Time from start of N_2O administration to discontinuation.
‡ Time from end of N_2O administration to first oral intake.
§ Time from end of N_2O administration to postoperative ear pressure measurement.
¶ Time from end of N_2O administration to discharge.

age, weight, the time from discontinuation of nitrous oxide to the first oral intake, the time from discontinuation of nitrous oxide to middle ear pressure measurement, or the total recovery time (table 2).

Abnormal negative ear pressures postoperatively were recorded unilaterally in 18% of cases and bilaterally in 62% of cases. Pressures were normal bilaterally in 20% of patients. The incidence of vomiting was not higher in patients with either unilateral or bilateral abnormal ear pressures (table 3).

Children aged 8 yr and under had a greater incidence of postoperative negative ear pressures (table 4).

Analyses were performed, but failed to demonstrate any relationship between vomiting and two age groups (8 yr and under *versus* over 8 yr), sex, endotracheal intubation, dental *versus* other surgery, or codeine analgesia. Upper respiratory tract infection within 1 week was not found to be associated with a higher incidence of abnormal postoperative middle ear pressure.

DISCUSSION

Postoperative nausea and vomiting may have many causes, including pain itself,[6] the use of narcotic analgesics,[7-9] stimulation of extraocular muscles,[9,10] peritoneal traction and subsequent ileus, and swallowed blood.[11] Preexisting neurological or gastrointestinal

TABLE 3. Comparison of Postoperative Ear Pressures and Vomiting

	Ear Pressure			
	Normal	Unilateral Abnormality*	Bilateral Abnormality†	Total
Vomiting	2	1	11	14
No Vomiting	10	10	26	46
Total	12	11	37	60

P = NS.
* Where a greater than 5 cm H_2O negative change in middle ear pressure is recorded in one ear.
† Where a greater than 5 cm H_2O negative change in middle ear pressure is recorded in both ears.

TABLE 4. Comparison of Postoperative Ear Pressures and Age

	Ear Pressure			
Age	Normal	Unilateral Abnormality*	Bilateral Abnormality†	Total
≤8 years	2	4	22	28
>8 years	10	7	15	32
Total	12	11	37	60

$P < 0.05$.
* Where a greater than 5 cm H_2O negative change in middle ear pressure is recorded in one ear.
† Where a greater than 5 cm H_2O negative change in middle ear pressure is recorded in both ears.

disorders and certain operative procedures, particularly head and neck and extraocular muscle procedures, predispose to vomiting.[6] To examine the effect of negative middle ear pressure secondary to nitrous oxide administration on vomiting, all patients received nitrous oxide, and patient's preoperative ear pressures served as a control, as postoperative abnormal ear pressures were defined as greater than −5 cm H_2O, change from the preoperative measurement. Patients and procedures with a known high incidence of vomiting were excluded. Intraperitoneal procedures and those in which adequate analgesia could not be obtained with the use of infiltration or regional analgesia, acetominophen, or codeine were also excluded. This eliminated the contribution of ileus, pain, and the use of morphine and meperidine to incidence of postoperative vomiting.[7-9] Lerman *et al.* demonstrated no increased vomiting with the use of codeine *versus* acetominophen in outpatient pediatric anesthesia after strabismus repair.[9]

Nausea, a subjective symptom, is very difficult to assess in children, and was, therefore, not studied. All patients were followed for 24 h postoperatively. Late vomiting occurred in 15% of cases, thus confirming that studies which document only early vomiting will underestimate the true incidence of postoperative vomiting.

A previous study in children suggested that all pediatric patients developed negative middle ear pressures after nitrous oxide exposure.[5] The present study shows that at least 20% of children have normal ear pressures prior to discharge, and that this is more likely in children greater than age 8 yr. This may be a result of maturation of the junction of the bony and cartilaginous portion of the middle ear, the isthmus, which occurs after age 6 yr. The eustachian tube is then less compliant, and collapse and dysfunction are less likely.[12]

The association between longer duration of anesthesia and vomiting has been reported.[11] The mechanism of increased vomiting with more prolonged nitrous oxide exposure has been suggested to be due to increased gastric distention. This may be exacerbated by

air swallowing or gastric inflation by ventilation *via* a mask prior to intubation.[13] No increase in vomiting was seen in tracheally intubated patients who would have received positive pressure mask ventilation prior to intubation. Nitrous oxide anesthesia does not affect bowel motility.[14]

We found no association between a history of recent upper respiratory infection and negative postoperative ear pressure. However, all admission tympanograms were normal, suggesting that preoperative eustachian tube function in this group was normal, despite a recent upper respiratory tract infection. A recent study has questioned any association between the use of nitrous oxide and development of postoperative nausea and vomiting in adults. Female gender, a younger age, and a previous history of nausea and vomiting were found to be associated with vomiting.[1] Although 60% of cases in this study were female, 41% were under age 12 yr and likely prepubertal. No association between female gender and vomiting was found.

In summary, we found no association between postoperative negative middle ear pressure and postoperative vomiting in outpatient pediatric patients after nitrous oxide and halothane anesthesia.

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Improving Arterial Oxygenation during One-lung Ventilation

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Maintaining adequate oxygenation during one-lung ventilation (OLV) for thoracic surgery is often a problem.[1,2] Studies have shown a significant incidence of Pa_{O_2} values less than 70 mmHg in spite of high inspired oxygen concentrations (FI_{O_2}) when the non-dependant lung (ND-lung) is allowed to collapse.[3] Application of continuous positive airway pressure (CPAP) with an FI_{O_2} of 1.0 to the ND-lung has been reported to be an effective method of improving Pa_{O_2} during OLV without interrupting surgery and re-inflating the ND-lung.[4] However, subsequent human studies have not found application of CPAP to produce consistantly satisfactory oxygenation.[5,6] Published human studies on CPAP during OLV have not detailed the method by which the CPAP was applied to the ND-lung. Allowing the ND-lung airway pressure (Paw) to fall to atmospheric pressure (Patm) for even a short period may result in collapse of small airways which will not be re-opened by clinically useful levels of CPAP.[7] However, application of CPAP 5 cm or more to the extremely compliant[8] ND-lung after the thorax is open results in a lung that stays at a high volume. This high volume combined with

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