Middle Ear Pressure Changes after Nitrous Oxide Anesthesia and Its Effect on Postoperative Nausea and Vomiting

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Objectives/Hypothesis: This study was designed to explore the relationship between changes in middle ear pressure associated with inhalational anesthesia and the incidence of postoperative nausea and vomiting (PONV). Study Design: Prospective, randomized. Methods: Middle ear compartment pressures were measured by tympanometry in 27 randomly assigned knee arthroscopy patients throughout the surgical procedure as well as into recovery. Results: A positive correlation between the maximum positive pressure (MPP) and maximum negative pressure (MNP) gradient and PONV was demonstrated (P < .05). The incidence of PONV in the nitrous oxide (N₂O) treatment group was 6 of 16 patients, whereas only 2 of 11 patients in the control group developed nausea, vomiting, and vertigo symptoms. Those patients that did not experience PONV demonstrated a median MPP of 155 with a median MNP of -52. The patients that experienced PONV exhibited a median MPP of 179 with a median MNP of -164. This demonstrates a significant increase in the incidence of PONV in the N₂O treatment group. Conclusions: Barometric changes in the middle ear contribute to the incidence of PONV induced by N₂O. Key Words: Middle ear, pressure, anesthesia, nitrous oxide, postoperative nausea and vomiting.

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INTRODUCTION

Changes in middle ear pressure during anesthesia have been reported to range from +400 mm H₂O (392 daPa) during nitrous oxide administration and as low as −500 mm H₂O (−490 daPa) after its cessation. Normally, pressures between the middle and outer ear are equilibrated by the actions of the tensor palati and levator palati muscle contractions and opening of the eustachian tubes during “deglutition.” Normally, pressure equalization is a passive phenomenon occurring simultaneously with tube opening. During anesthesia, pharyngeal muscle reflexes are obtunded, which may further delay the pressure equalization.

Nitrous oxide is a commonly used inhaled anesthetic that provides amnesia and analgesia. N₂O diffuses from the blood into air-containing cavities within the body faster than nitrogen diffuses out. This results in a transient increase in either the pressure or the volume of the cavity, depending on the distensibility of its walls. The middle ear represents an air-filled and relatively noncompliant space in the body where such an increase in pressure can occur. Decreased middle ear pressures occur during the recovery from inhaled anesthesia as rapid diffusion into the blood creates negative pressure. Positive pressure generated within the middle ear during N₂O anesthesia is readily released through the eustachian tube. However, negative middle ear pressure is less easily equilibrated. N₂O is also associated with postoperative nausea and vomiting (PONV). Negative pressure alone has not demonstrated a relationship with the development of PONV. Stimulation of the vestibular system through the displacement of the round window membrane may result from the rapid change in middle ear compartment pressure. This change from positive to subatmospheric pressure may contribute to nausea and vomiting after nitrous oxide anesthesia.

PONV is distressing and uncomfortable for patients. PONV also carries the risk of severe postoperative complications and is associated with additional costs. The etiology of PONV is multifactorial. Risk factors include the patient’s personal characteristics, medical condition, type of anesthesia administered, type of surgery performed, and postoperative factors. The ever-increasing number of same-day surgeries requires a rapid return to normal activities. The impact of such a middle ear pressure gradient and PONV has not been fully explored. We undertook the following study to determine whether middle ear pressure, as measured by tympanometry, could predict those patients with an increased potential for PONV.
MATERIALS AND METHODS

Patients

The study was reviewed and approved by the Institutional Review Board at the Veteran’s Administration Western New York Health care System. Twenty-seven adult patients scheduled for elective arthroscopic knee surgery under general anesthesia with isoflurane and oxygen were randomized to receive either nitrous oxide or air (FIO2 = 0.35). Exclusion criteria included preoperative nausea and vomiting, a history of motion sickness, current use of antiemetics, pre-existing otologic, labyrinthine or neuro-otologic diseases, and any contraindication for general anesthesia. The anesthetic induction and maintenance for the two groups were identical except for the administration of N2O.

Measurements

Tympanometry was performed with the Grason Stadler GSI-38 Auto Tymp (Grason-Stadler, Inc. Milford, NH) middle-ear analyzer. Tympanometry involves the measurement of compliance of the space within the portion of the external ear canal between the tympanic membrane and the probe tip as pressure varies in the ear canal. The resultant tympanogram graphically displays air pressure in the abscessa and also compliance values. The location of the peak along the abscissa provides an indirect measure of the middle ear pressure behind the tympanic membrane. A baseline tympanogram (B0) was obtained before the initiation of anesthesia. After the induction of anesthesia, tympanograms were obtained every 30 minutes throughout the operative procedure (A1–A4). On arrival of the patient at the phase one postanesthesia care unit, the first measurement was recorded as R and was repeated every 30 minutes (E1–E4). Additional tympanograms were obtained if the patient experienced nausea, vomiting, or vertigo symptoms. The left ear was designated the study ear in all patients for the convenience of equipment location in the operating room. The same ear was used to obtain tympanograms throughout the study. The incidence of postoperative nausea, vomiting, and vestibular symptoms such as dizziness and vertigo were ascertained by a blinded observer in the postanesthesia care unit. One hundred sixty-one observations were recorded.

Statistical Analysis

One-way analysis of variance (ANOVA) was used to analyze middle ear pressures among the groups. Bonferroni post hoc analysis was applied. Fisher’s exact test with chi-square cross tabulation was used to identify the difference in the incidence of PONV. P values of less than .05 were considered significant.

RESULTS

The groups were comparable in age, sex, type and duration of surgery, and the amount of narcotics administered. The overall incidence of emesis in the nitrous oxide group was 45%, which was significantly higher than a 10% incidence in the control group (P < .05).

The barometric effects of nitrous oxide became evident immediately after induction of anesthesia and continued to be higher than the comparable measurements in the control group. After cessation of inhaled anesthetic, there was a sudden drop in the middle ear pressures in the nitrous oxide group, whereas in the control group, the middle ear pressure gradually decreased to its baseline levels (Fig. 1). Mean gradient of the middle ear pressure in N2O group (300.6 ± 23.1 daPa) was significantly higher than the pressure gradient in controls (166.8 ± 27.9 daPa, P < .01) (Fig. 2).

Data analysis of 27 participants demonstrates a positive correlation between the maximum positive pressure (MPP) to maximum negative pressure (MNP) gradient and PONV. Patients in the treatment group who experienced PONV demonstrated a larger gradient between the MPP and MNP. Those patients who did not experience PONV demonstrated a median MPP of 155 with an MNP of −52. The patients who experienced PONV exhibited a median MPP of 179 with a median MNP of −164. The pressure gradient in the patients with PONV was 343.3 ± 81.2 daPa, which was significantly higher than in the control group (207 ± 57 daPa, P < .05) (Fig. 3).

Although the effect of the type of breathing appliance (e.g., endotracheal tube [ETT, 198.5 ± 50.7 daPa] vs. laryngeal mask airway [LMA, 290.4 ± 48.9 daPa]) on PONV did not reach significance, the use of LMA significantly increased the pressure gradient in the middle ear when it was associated with administration of N2O (P < .05).
DISCUSSION

Chinn et al.3 demonstrated that middle ear pressure fluctuation is more common when a volatile anesthetic is combined with N2O. In addition, they proposed that physiologic differences between subjects might play a role in the passive opening of the eustachian tube during positive pressure. This supports the finding of Elam et al.14, who demonstrated that the effectiveness of positive pressure regulation in the middle ear during N2O anesthesia was correlated with the size of the mastoid bone.

The mechanisms by which pressure changes may induce nausea and vomiting are not well defined because these symptoms can result from labyrinthine and vestibular etiologies as well as central nervous system dysfunction. Endolymphatic hydrops (Menière’s disease) may induce both nausea and vomiting in addition to vertigo, tinnitus, and fluctuant hearing. The underlying factor in hydrops is a change in labyrinthine pressure associated with the hydrops. Certainly, rapid changes in middle ear gaseous pressure are likely to be transmitted directly to the labyrinth and vestibular system by way of the round window and to a lesser extent the oval window. It is logical to assume that such pressure changes play a likely role in the induction of PONV.

PONV as sequelae of N2O administration can also result from increased sympathetic activity and central mechanisms that induce activation of the chemoreceptor trigger zone (CTZ). The CTZ is thought to lie in the highly vascularized area postrema in the floor of the fourth ventricle.15 The CTZ is a major afferent to the nucleus tractus solitarius15 and is replete with receptors thought to play a role in nausea and vomiting.16 Studies in a rat model suggest that N2O may activate mesocortical and medullary periventricular dopaminergic systems in the CTZ that are responsible for emesis.17 This factor may have contributed to the incidence of PONV in our N2O group.

A concern for the investigators was that this study was limited by the inability of this tympanometer to measure positive pressure greater than 200 daPa. However, a P value of .01 suggests a strong relationship between the sudden change in pressure gradient from positive to negative pressure postoperatively and PONV, and that N2O contributes to these pressure dynamics during inhalational anesthesia. Another concern was whether the variability in airway appliance used to maintain the airway during anesthesia could affect the rate of PONV. Patients received either an ETT or LMA to facilitate inhalational anesthetic delivery. The insufflation of the middle ear with N2O or eustachian-tube obstruction related to the use of the LMA could possibly have contributed to the generation of positive pressure. However, the difference in PONV and the pressure gradient were not statistically significant when airway appliance was evaluated as a
factor \((P = .11)\). Also worthy of mention was that the focus of this study evaluated early PONV. Late vomiting after discharge has been reported to be as high as 15%. This may have underestimated the true incidence of postoperative vomiting.

CONCLUSION

Our data suggest that there is a correlation between the gradient of the MPP to MNP that a patient experiences during the course of the perioperative period and PONV. We conclude that barometric changes in the middle ear contribute to the incidence of PONV induced by \(\text{N}_2\text{O}\).

BIBLIOGRAPHY