Effect of Nitrous Oxide on Middle Ear Mechanics and Hearing Acuity

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Hearing loss was observed in a few patients following nitrous oxide anesthesia. We hypothesized that the defect could result from changes in middle ear pressure incident to increased airway pressure and/or differential solubility of nitrous oxide and nitrogen. Consequently, we tested middle ear mechanics (Zwislocki Acoustic Bridge) and hearing acuity before, during and after breathing nitrous oxide and nonnitrous oxide mixtures, both with and without positive pharyngeal airway pressure.

Decreased compliance and increased resistance occurred in all instances but was greater when nitrous oxide was present. Positive airway pressure appeared to be without effect. The observed changes persisted only in patients receiving N2O anesthesia for adenotonsillectomy. A conductive-type hearing loss of short duration was also noted in this group.

We have recently observed several patients who complained of temporary hearing loss following anesthesia. All were patients given anesthesia for minor surgical procedures. A circumstance common to all was inhalation by mask of high tensions of nitrous oxide. None had instrumentation within the upper airway. Search of the literature failed to reveal previously recorded instances of similar hearing loss under these conditions.

We considered that hearing impairment might develop as the result of at least two conditions: (1) a pressure change in the middle ear resulting from the differential solubility of nitrous oxide and nitrogen, and (2) similar pressure changes incident to positive pharyngeal airway pressure. Malfunction of the Eustachian tube could prolong pressure changes in either situation, because the canal normally acts to maintain ambient pressures within the middle ear.

The problems inherent in air-filled body cavities during induction and emergence from nitrous oxide anesthesia have been discussed by Eger and Saidman.1 Briefly, these occur because nitrous oxide is some thirty times as soluble as nitrogen in blood and is frequently administered in tensions approximating those of nitrogen in air. On induction of anesthesia, nitrous oxide will enter an air-filled cavity in greater quantity than nitrogen will escape, producing an increase in pressure and/or in size of the cavity. On emergence from anesthesia the reverse should occur, more molecules of nitrous oxide will leave the gas-filled cavity than enter (nitrogen), producing below ambient or negative pressure in a fixed wall structure such as the middle ear.

Since none of the aforementioned patients had endotracheal anesthesia positive airway pressure could have been transmitted to the middle ear via the Eustachian tube producing the changes that led to a diminution of hearing sensitivity. Consequently, this study was undertaken to investigate changes in hearing sensitivity and middle ear mechanics that might be produced by nitrous oxide or positive airway pressure, and might persist into the postanesthetic period.

Methods

Middle ear mechanics were investigated by measuring impedance of sound energy trans-
mission at the plane of the ear drum. To review briefly the pertinent physiology, energy reaching the tympanic membrane may be (1) transmitted to the oval window, (2) absorbed by middle ear structures, or (3) reflected from the membrane. The degree to which energy is reflected depends upon characteristics of structures medial to the tympanic membrane, mainly the ossicular chain and cochlea. A reflected energy wave is of the same frequency as the incident wave but phase and/or amplitude relations may differ. It is, therefore, possible to compare incident and reflected waves and to determine impedance characteristics at the plane of the tympanic membrane (reflecting surface).

Resistance and compliance in this study were measured by means of a Zwislocki Acoustic Bridge. The principle of this instrument is analogous to that of the Wheatstone Bridge, in that a variable but known impedance is adjusted to match the unknown impedance by nulling the output of the bridge.

The instrument is placed in the external auditory canal and a pure tone wave is directed both toward the tympanic membrane and toward the adjustable and measurable impedance. Adjustment of measurable impedance so that the reflected waves are the same, provides a description of the unknown impedance. The acoustic bridge indicates resistance in arbitrary units. Change in resistance is inversely related to the change in arbitrary units. Compliance is measured in cubic centimeters of an equivalent volume of air.

Impedance has components of resistance and reactance. Compliance and inerterance combine to give the property of reactance. The Zwislocki Bridge describes only the contribution of compliance to reactance. Changes in auditory resistance are largely related to frictional resistance in the ossicular chain. Compliance is related to elastic features of the membrane and elastic properties of the oval and round windows.

Hearing sensitivity was measured at 250, 500, 1,000, 2,000 and 4,000 cycles per second before and after the conditions of breathing.

Table 1 indicates the number of subjects and conditions under which they were studied. These persons varied in age from 6 to 88 years and were either patients from the operative schedule or volunteer hospital personnel. They were screened to exclude perforated tympanic membranes or apparent infection within the ear. Anesthetized subjects received preanesthetic belladonna drugs and mild sedation after preliminary measurements were made. Measurements of resistance and compliance at 250 and 1,000 cycles per second were made before, during and after the procedures listed in table 1. Measurements during anesthesia or pressure breathing were made after a minimum of 20 minutes. Positive airway pressure in this study is defined as continuous positive pressure with a maximum of 20 centimeters of water at end expiration. Final hearing tests and impedance measurements were made from 1 to 24 hours after the test inhalation. The audiologist determined when subjects had recovered sufficiently to be cooperative.

The above arrangement allowed us to measure effects of raised airway pressure with and without nitrous oxide and of nitrous oxide, with and without raised airway pressure. In addition, we collected data during and after
surgery involving the Eustachian orifice (adenotonsillectomy).

Three Lindquist type I analysis of variance were performed to answer these questions. The chosen level of significance was 0.05.

Results

Compliance and Resistance. The results of these measurements (mean values) are shown in figures 1 and 2. All groups developed a statistically significant increase in resistance and decrease in compliance during the test period of inhalation at both frequencies tested. Those not receiving nitrous oxide (oxygen alone or halothane-oxygen) developed changes of much lesser magnitude than those receiving nitrous oxide. All changes observed returned to or toward pretest values except the reduced compliance noted in the adenotonsillectomy group (fig. 3). Compliance remained at low values in the post-test period for this group of subjects.

Positive airway pressure did not appear to alter resistance or compliance measurements induced by nitrous oxide.

Hearing Sensitivity. The adenotonsillectomy group was the only group with changes in the postoperative air conduction audiogram. Figure 4 compares the mean air conduction values for both right and left ears of eight such subjects. This decrement in hearing sensitivity disappeared in two or three days.
Discussion

The changes in mechanics noted here may reasonably be expected to result from changes in middle ear pressure. Because the ossicles are attached to the drum, increases (or decreases) in pressure within the middle ear would displace and/or stabilize the drum and thus change the functional characteristics of the ossicular chain and the drum. This would be detected by the acoustic bridge as a change in reflected sound wave. Under circumstances similar to ours, Thomsen, Terkildsen, and Armfled recently observed a rise in middle ear pressure in humans during administration of nitrous oxide. They incorporated in their study a method of measuring middle ear pressure directly. Middle ear pressure rose initially and then fell towards baseline during the administration of nitrous oxide. Their studies were on normal humans and the Eustachian tube served to decompress the ear. With malfunction of the Eustachian tubes, therefore, pressures could become higher and/or persist longer. Such changes may be of greater magnitude after emergence from anesthesia when a relatively rapid exodus of nitrous oxide from the middle ear results in negative pressure. The Eustachian tube does not serve to equilibrate pressures as readily when pressure within the ear is less than the ambient as it does when middle ear pressure is greater than ambient.

Thus, the combined finding of decreased hearing acuity and persistent decrease in compliance in the group receiving nitrous oxide and operations near the Eustachian orifice may be related to the effects of nitrous oxide in patients with malfunction of the Eustachian tubes.

We have seen spontaneous rupture of the tympanic membrane during nitrous oxide anesthesia. This could have been the result of an increase in middle ear pressure with failure of the Eustachian tube to decompress the middle ear. We have also seen children following induction of anesthesia for myringotomy who had an apparent “cure”; that is, the tympanic membrane returned towards the normal position. Both phenomena could be explained on the basis of an early increase in middle ear pressure caused by the diffusion of nitrous oxide into this space.

We have observed one adult patient who developed postoperative serous otitis associated with a conduction hearing loss that persisted for two weeks. Serous otitis or the entrance of serous fluid into the middle ear may be caused by relatively small degrees of negative pressure. This patient admitted on further questioning to have been “almost over a cold.”

Those patients whose hearing loss postanesthesia inspired our study had anesthesia of short duration with little or no postoperative pain and, therefore, a change in hearing was readily apparent to them. This phenomenon may occur more often than is recognized by the patient who is either too ill or
perhaps heavily sedated for 24–48 hours postoperatively.

Summary

The changes measured suggest that the differential solubility of nitrous oxide and nitrogen is responsible for change in middle ear mechanics, and that this change may be prolonged and contribute to postoperative hearing loss if normal equilibrating mechanisms are comprised.

Anesthesia

FETAL pH Determinations of fetal scalp blood pH were made serially during labor. The first determination was made when the cervix was dilated 4 cm. The fetal scalp was made hyperemic with Frigiderm, and then silicone applied to promote the formation of a discreet drop of blood. The scalp was grasped with an Allis clamp, and a puncture made with a knife blade. Blood was collected in a capillary tube, and analyzed with a Radiometer pH meter. In addition, umbilical artery and vein blood pH were determined at birth. The pH of the fetal scalp blood was found to usually lie between that of the umbilical artery and vein. There was a good correlation between Apgar score and scalp blood pH. pH usually decreased slightly during labor. There was a poor correlation between clinical signs of distress, such as changes of fetal heart rate or passage of meconium, and scalp pH. Determination of scalp pH in the unborn may aid in determining the need for prompt delivery when fetal distress is present. (McDonald, J. S.: \textit{Evaluation of Fetal Blood pH as a Reflection of Fetal Well-Being}, Amer. J. Obstet. Gynec. 97: 912 (April) 1967.)


PARACERVICAL BLOCK A total of 167 patients ranging between 15 and 55 years had dilatation and curettage with paracervical block anesthesia using 1 and 2 per cent lidocaine. Most, but not all of the patients had meperidine and atropine premedication. Good anesthetic results were obtained in 168 patients and fair to poor in 8, due to inaccurate placement of the anesthetic agent posterolaterally. Only one patient had transient faintness and dizziness, which was believed to be secondary to an allergic drug reaction. (Van Praagh, I. G. L., and Pocey, W. G.: \textit{Paracervical Block Anesthesia for Dilatation and Curettage}, Amer. J. Obstet. Gynec. 29: 167 (Feb.) 1967.)

References


