Preoperative Evaluation of Ossicular Chain Abnormality in Patients With Conductive Deafness Without Perforation of the Tympanic Membrane

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Objective: To evaluate the usefulness of pure-tone audiometry, tympanometry, and liquid and acoustic reflex (AR) tests in the differential diagnosis of ossicular fixation and discontinuity.

Design: A prospective clinical trial.

Setting: Tertiary referral center.

Patients: Thirty-nine patients (46 ears) undergoing operations at University of Tsukuba Hospital, Tsukuba, Japan, from 1990 through 2003 for conductive deafness without perforation of the tympanic membrane. Clinical examinations for the preoperative diagnosis included pure-tone audiometry, tympanometry, and liquid and AR tests. We compared the preoperative diagnosis with the surgical findings.

Results: Although neither pure-tone audiometry nor tympanometry contributed to the differential diagnosis of ossicular chain abnormality, liquid and AR test results showed a significant difference between fixation and discontinuity of the ossicular chain. With the liquid test, bone conduction at lower frequencies was improved by filling the external auditory canal with water at lower frequencies in cases of ossicular fixation. In contrast to the findings observed in ossicular fixation, no improvement of the threshold of bone conduction was recognized at any frequency in the ears with ossicular discontinuity. In ipsilaterally stimulated AR, the reversed pattern was the most marked at 2000 and 500 Hz in ossicular fixation and discontinuity, respectively.

Conclusion: Liquid and AR tests are reliable examinations for the differential diagnosis of ossicular fixation and discontinuity.


The Middle Ear Transmits sound energy from the air space in the external auditory canal to the fluid-filled cochlea. This coupling is accomplished through the vibration of ossicles of the middle ear. Although the routine measurement systems of acoustic immittance such as tympanometry are fast and easily tolerated by most patients, they generally do not yield precise information about the nature of ossicular abnormalities, i.e., ossicular fixation or discontinuity. Therefore, preoperative diagnosis of the nature of ossicular chain abnormality is often difficult in patients with conductive hearing loss without perforation of the tympanic membrane.

A contraction of the stapedius muscle results in a change in the acoustic impedance of the ear. A 220- to 226-Hz probe tone is commonly used to examine the acoustic impedance in commercially available devices. The impedance increases at this frequency of the probe tone by a contraction of the stapedius muscle. The reversed pattern in the ipsilateral acoustic reflex (AR) consists of decrease of the impedance when the ipsilateral ear is acoustically stimulated with a high-intensity sound. For some years, studies from our laboratory have observed that ears with ossicular chain abnormality, including ossicular fixation and discontinuity, could exhibit a reversed pattern in ipsilateral AR. Those previous studies suggested that the reversed pattern was most evident at 2000 Hz in ossicular fixation and at 500 Hz in ossicular discontinuity when the reversed pattern was evaluated at 500, 1000, and 2000 Hz. Such findings strongly suggest that the reversed pattern of AR has a potential clinical application in the differential diagnosis of ossicular fixation and discontinuity.

Impedance of the tympanic membrane clearly affects the total impedance...
of the middle ear. Resistance, mass, and stiffness of the tympanic membrane become negligible when the external auditory canal is filled with water and sound is transmitted through the water to the ossicular chain. In this situation, total impedance of the middle ear largely depends on the condition of the ossicular chain. Figure 1 shows schematic and photographic representations of the liquid test. As shown in Figure 1A, the bone-conduction threshold was measured without water at first, with the vibrator placed at the cavum conchae. After the external auditory canal was filled with water, the threshold was measured again. Sound energy was transmitted to the cochlea through the water and ossicles or through temporal bone (Figure 1B and C). The water-conduction threshold was generally better than the bone-conduction threshold in subjects with normal hearing. Water conduction was deteriorated in cases of ossicular fixation (Figure 1B). Sound energy was transmitted mainly through the temporal bone with or without water in patients with ossicular discontinuity (Figure 1C). Thus, the liquid test is potentially quite useful in the differential diagnosis of conductive hearing loss.

A reliable presurgical diagnosis of ossicular chain abnormality is important for surgical planning and informed consent. A previous report from our laboratory found that AR and liquid tests were useful for the preoperative diagnosis of ossicular fixation due to ossified stapedius tendon. The purpose of the present study was to evaluate the effectiveness of the AR and liquid tests in the differential diagnosis of conductive hearing loss without perforation of the tympanic membrane.

METHODS

SUBJECTS

Thirty-nine patients (46 ears) with otosclerosis, ossicular anomaly, or head trauma without perforation of the tympanic membrane underwent middle ear surgery at University of Tsukuba Hospital, Tsukuba, Japan, from 1990 through 2003. The patient group consisted of 17 male and 22 female patients. The mean age was 21.2 years. All patients underwent preoperative evaluation by means of pure-tone audiometry, tympanometry, and AR and liquid tests. The patients were divided into the following 2 diagnostic groups: (1) those with ossicular fixation, consisting of 10 patients (12 ears) with otosclerosis and 16 (20 ears) with ossicular anomaly; and (2) those with ossicular discontinuity, consisting of 10 patients (11 ears) with ossicular anomaly and 3 (3 ears) with head trauma.

The principles outlined in the Declaration of Helsinki were followed in the present study.

TYMPANOMETRY AND AR MEASUREMENT

Tympanometry and AR were simultaneously examined with standard equipment (Zodiac 901 middle ear analyzer and model Z072; Madsen, Copenhagen, Denmark). To evoke the AR, 500-, 1000-, and 2000-Hz tone bursts of 1.5-second duration were presented to the ipsilateral ear. If no reflex was elicited, the stimulation was increased in 5- or 10-dB steps to a maximum hearing level of 125 dB with the model Z072 middle ear analyzer and 100 dB with the Zodiac 901 middle ear analyzer.

In ipsilaterally stimulated AR, the reversed pattern was sometimes recognized in the abnormal ears. The amplitudes of the reversed pattern were evaluated at 500, 1000, and 2000 Hz.

RESULTS

PURE-TONE AUDIOMETRY FINDINGS

The most common audiometric configurations were upsloping or a reversed “cookie-bite” pattern in ossicular fixation (in 22 of 32 ears) and flat in ossicular discontinuity (in 6 of 14 ears). However, the reversed cookie-bite pattern was observed in 5 of 14 ears with ossicular discontinuity, and the flat pattern was also noted in 8 of 32 ears with ossicular fixation. The overall mean±SD pure-tone air-conduction threshold in these 46 ears was 54.1±11.8 dB, and the mean±SD bone-conduction threshold was 19.5±8.8 dB.

TYMPANOMETRY FINDINGS

Of the 32 ears in the ossicular fixation group, normal type A tympanograms were present in 21 (66%); shallow type A tympanograms, in 9 (28%); a deep type A tympanogram, in 1 (3%); and the other patterns (type B or C), in

LIQUID TEST

Pure-tone bone-conduction thresholds were measured at 250, 500, and 1000 Hz with a vibrator placed at the cavum conchae before and after the external auditory canal, and the cavum conchae were filled with water (audiometer model AA-61BN; Rion, Tokyo, Japan). The threshold shifts caused by filling the external auditory canal were evaluated.
The mean ± SD degree of threshold improvement achieved by filling the external auditory canal with water is shown in Figure 3. In the cases of ossicular fixation, ears with ossicular discontinuity, and contralateral ears with normal hearing.

No response was elicited in 19 ears, and the reversed pattern was observed in 27 ears. A representative reversed pattern is shown in Figure 2. The reversed pattern was most evident at 2000 Hz in 19 of 20 ears with ossicular fixation and at 500 Hz in all 7 ears with ossicular discontinuity. The overall accuracy of the reversed pattern in AR was 96% (26 ears).

**REVERSED PATTERN IN AR**

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**BONE- AND WATER-CONDUCTION THRESHOLDS IN LIQUID TEST**

Results of the liquid test were examined in the 32 cases of ossicular fixation and the 14 cases of ossicular discontinuity. The mean ± SD degree of threshold improvement achieved by filling the external auditory canal with water is shown in Figure 3. In the cases of ossicular fixation, bone conduction was slightly improved by filling the external auditory canal with fluid at lower frequencies, ie, 250 and 500 Hz, showing a declining pattern. No improvement of the threshold was recognized in the ears with ossicular discontinuity, which showed a flat pattern. Figure 3 also shows the result in the normal contralateral ear (n = 11), which revealed a normal pure-tone hearing threshold and normal tympanogram and AR findings. Based on these results, declining and flat patterns in the liquid test results strongly suggest ossicular fixation and discontinuity, respectively, in the preoperative evaluation of ossicular chain abnormality. Indeed, 11 (79%) of 14 ears with ossicular discontinuity showed the flat pattern in liquid test results, and 30 (94%) of 32 ears with ossicular fixation exhibited the declining pattern. Overall accuracy of the liquid test was 89% (41 ears).

Browning et al3 reported that static compliance was less than 0.2 in 38% of their patients with otosclerosis and suggested that standard tympanometry is generally not sensitive enough to diagnose ossicular fixation. It has been suggested that multifrequency tympanometry is of value for evaluating the ossicular chain abnormality. However, its complexity has interfered with clinicians’ routine otologic examination for preoperative diagnosis.

A shallow type A tympanogram (static compliance, <0.3 in this study) was observed in only 28% of ossicular fixation cases, and a deep type A tympanogram (static compliance, >1.0 in this study) was observed in 21% of ossicular discontinuity cases. Based on the present results, we concluded that neither standard tympanometry nor audiometric configurations in pure-tone audiometry were useful for differential diagnosis of ossicular chain abnormality.

The most important findings in the present study were that AR (evaluating the reversed pattern) and liquid tests are noninvasive and reliable methods for the assessment of conductive hearing loss without perforation of the tympanic membrane. In addition, these tests are inexpensive and can be performed within a reasonable time.

Impedance audiometry generally uses 220- or 226-Hz pure tone of 85 to 90 dB as a probe tone. When the probe and reflex-eliciting tones of enough high sound pressure are presented to the same ear, a nonphysiological artifact is observed as a decrease in impedance that is time locked to the eliciting tone.8,9 It has been known that this artifact is observed only in compliant cavities and never occurs in hard-walled cavities, suggesting that this artifact may be associated with compliant tympanic membrane.8 A reversed pattern on the ipsilateral AR is considered to be generated through nonphysiological mechanisms when a normal AR is absent.2,8 We consider that a reflex-eliciting tone of sufficiently high intensity itself induces eardrum vibration of large amplitude and might affect the impedance at the tympanic membrane. A reversed pattern of ipsilateral AR was most
evident at 500 Hz in the ear with ossicular discontinuity and at 2000 Hz in ossicular fixation, probably because the resonance frequency of vibration of the tympanic membrane was less than 800 Hz and more than 1200 Hz in ears with ossicular discontinuity and fixation, respectively.\textsuperscript{2,6,7,10} Although the possible sources of the reversed pattern of ipsilateral AR have not been thoroughly explored, the present finding that the amplitude of the reversed pattern was dependent on the frequency of the eliciting tone was very useful for diagnosis of ossicular chain abnormalities.

Sound pressure equal to or greater than 100 dB was generally required to evoke the reversed pattern in the present study. The AR test is useful for differential diagnosis of ossicular chain abnormality only when the test equipment allows stimulus of high-sound pressure.

In the liquid test, the water-conduction threshold was generally better than the bone-conduction threshold in subjects with normal hearing (Figure 3). The thresholds were improved at lower frequencies, ie, 250 and 500 Hz, in the patients with ossicular fixation. No conductive improvement was observed in those with ossicular discontinuity. The present study demonstrated that the difference in the threshold improvement was quite useful for differential diagnosis of ossicular fixation and discontinuity.

In conclusion, the liquid test and evaluation of the reversed pattern in AR are reliable examinations for the differential diagnosis of ossicular fixation and discontinuity.

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