Transient Evoked Otoacoustic Emissions and Pseudohypacusis

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Abstract
The audiologic diagnosis of pseudohypacusis continues to challenge the clinical audiologist. The introduction of otoacoustic emissions (OAEs) to the test repertoire of the audiologist may prove valuable in the evaluation of pseudohypacusis. This report highlights five cases in which transient evoked otoacoustic emissions (TEOAEs) were used to cross-check the validity of subjective audiologic thresholds. Relationships of TEOAEs to other objective measures of audiologic thresholds are shown to substantiate the value of the procedure for the diagnosis of pseudohypacusis. Suggestions for the use of OAEs in cases of pseudohypacusis are discussed.

Key Words: Malingering, otoacoustic emissions, pseudohypacusis

During the past 40 years, several procedures have been used to identify pseudohypacusis. The most obvious routine audiometric sign of pseudohypacusis is a disagreement (usually 15 dB or more) between pure-tone averages and speech reception thresholds, with speech thresholds typically better. Although this does not give an accurate indication of thresholds, it alerts the audiologist to the possibility of pseudohypacusis. The most widely used special test is the Stenger, either pure tone or speech; however, this test requires at least a 20-dB difference between ears, does not give precise threshold measures, and has been shown to have an unacceptably high rate of inaccuracy. Other measures include the Bekesy audiometry, the sensorineural acuity level (SAL) test, the Doerfler-Stewart test, the acoustic reflex, the Lombard test, and pure-tone and speech-delayed auditory feedback (Rintelmann and Schwan, 1991).

Electrophysiologic measures exist that may help to both identify and quantify pseudohypacusis (Hall, 1992). Traditionally, the most accurate but infrequently used measure was the slow cortical potential (N1-P2). This test can provide frequency-specific information, and the response has been present close to behavioral threshold. The major limitation of the test is that it is time-consuming: approximately 4 minutes per frequency to administer, in addition to the time spent on instrumentation setup and application of electrodes. The auditory brainstem response (ABR) and the middle latency response (MLR) tests using click stimuli are also recordable close to behavioral threshold. While the click-evoked ABR is limited to providing information about the range of hearing from 1000 to 4000 Hz, the MLR can provide frequency-specific results. However, administration of the ABR and MLR, like that of the slow cortical potential, is time-consuming. Another promising clinical tool is the recording of otoacoustic emissions (OAEs) (Robinette, 1992). Otoacoustic emissions are generally subaudible sounds generated by an active response from the cochlea (most likely the outer hair cells) to various types of sounds. Otoacoustic emissions provide information about a wide range of audiometric frequencies. Both ears can be tested in approximately 3 minutes. Generally, when using the IL088 or IL092, click-evoked OAEs disappear when the hearing loss for the frequencies of interest reach approximately 30 dB HL, although
this must be interpreted cautiously (Kemp et al., 1990). The primary caveat is that emissions may give an unacceptably high false-positive identification rate of hearing loss. Therefore, presence of an emission is a good indicator that hearing sensitivity is better than 30 dB HL, but absence of an emission cannot rule out normal hearing.

We present below five interesting cases of pseudohypacusis. Patient histories and a comparison of ABR and behavioral results to OAEs are presented. These cases illustrate the utility of OAEs and the need for the clinician to be aware of the possible presence of pseudohypacusis.

**METHOD**

**Subjects**

We present results of five female patients (ages 10 to 31 years) who were evaluated in the audiology clinic at the Dartmouth-Hitchcock Medical Center (DHMC). None of these patients had a history that would raise one's index of suspicion for pseudohypacusis.

**Procedure**

Audiologic evaluations for each of the subjects were conducted in the conventional manner. In addition, immittance measures were derived for all five subjects. Transient evoked otoacoustic emission (TEOAE) tests were then conducted by staff audiologists experienced in TEOAE procedures according to recommendations for OAE measurement outlined by Kemp et al. (1990) for use with the IL088 analyzer.

All subjects were tested while seated comfortably in a sound-treated booth. To test TEOAEs, the probe was fitted to each patient's ear by using probe tips of our own design, constructed from compacted foam or rubber immittance probe tips. Special effort was made to firmly fit the probe deeply into the ear canal. In all subjects, a snug probe fit was maintained throughout the test session as indicated by the derived stability measures.

Stability measurements provide a monitor of proper probe fitting by representing the degree of correlation between the initial and final stimulus measurements. They are expressed as percentages. For the five patients in this report, probe stability measures ranged from 89 percent to 96 percent.

The stimuli generated by the IL088 analyzer were the standard 80-microsecond electric rectangular pulses presented at a rate of 50 per second at a level of 82 ± 2 dB peak SPL. The routine nonlinear default mode of presenting stimulus trains was used. In this setting, subsets of four clicks are presented: three are the same intensity, while one is 9.5 dB greater and phase inverted (Kemp et al., 1990). The stimulus bandwidth is 5 kHz, but actual width size varies depending on the probe fitting and the physical properties of each ear. In the present study, a total of 260 presentations of the stimulus train were collected (260 presentations × 4 clicks in each presentation × 4 subaverages collected in each of the two buffers = 2080 stimuli).

In this default mode of the IL088 analyzer, responses to the biologically generated acoustic stimuli and TEOAE stimuli are collected alternately into two buffers and are averaged. The response is windowed into 20-msec time frames. Contamination by acoustic stimulus ringing is controlled by eliminating the first 2.5 msec of the response. Responses are filtered by a forward-and-reverse-band-pass filter with 600 and 6000 Hz cut-offs and a reverse high-pass filter set at 200 Hz. The two averaged waveforms are superimposed and displayed on the main response panel. The response spectrum is calculated by taking the fast fourier transform of the two averaged waveforms.

The presence of an OAE response was determined based on criteria established previously (Vedantam and Musiek, 1991). First, the spectrum response level had to be 3 dB or more above the noise level. Second, at least some portion of the response had to be within 200 Hz of the examined center frequencies. Third, some portion of the response was required to be at least 200 Hz in width and within the specified frequency region of 1 kHz.

ABR measures were obtained using a 100-microsecond rarefaction click stimulus and insert receivers (ER-3A). A conventional recording montage was used with the active electrode at the high forehead, the reference electrode at the ipsilateral earlobe, and the ground electrode at the contralateral earlobe. Filter settings were 150 to 3000 Hz with a 5 dB-per-octave roll-off, and the stimulus repetition rate was generally 15 clicks per second. ABR threshold recordings were made initially at relatively high stimulus intensities then at decreasing intensities until a repeatable wave V could not be obtained.
MLR measures were obtained on some subjects using a 100-microsecond click stimulus. A single-channel recording was made with the active electrode at the vertex, the reference electrode at the ipsilateral earlobe, and the ground electrode at the contralateral earlobe. Impedance across electrodes was under 5 kΩ for all subjects for both the ABR and MLR. Filter settings were 30 to 250 Hz with a 6-dB roll-off, and the stimulus repetition rate was 11.1 clicks per second. Intensity functions were obtained in a manner similar to those for the ABR.

RESULTS

Case 1

Case 1 was a 10-year-old female. She was referred to the Dartmouth-Hitchcock Medical Center (DHMC) following multiple conflicting hearing tests taken at her school. The test results varied, ranging from borderline normal hearing to a severe hearing loss. At the mother's request, repeated tests were administered over approximately 1 year. The patient presented at DHMC with normal hearing sensitivity in the left ear and a sloping mild-to-moderate hearing loss in the right ear through 2000 Hz and a severe loss at 4000 Hz (Fig. 1A). These results differed from those of the previous tests, but the audiologist suspected problems with the reliability and validity of the pure-tone results. An otologic evaluation revealed no problems. Interestingly, in contrast to what is usually seen with pseudohypacusis, the pure-tone average (PTA) was significantly better than the speech reception threshold (SRT) (37 dB HL vs 53 dB HL). A robust TEOAE with an overall level of 11.3 dB SPL was found in the right ear (Fig. 1B). The spectrum of the TEOAE response and the ABR response waveform were consistent with normal hearing sensitivity in the 1000- to 4000-Hz range (Fig. 1C).
Case 2

Case 2 was a 17-year-old female who was referred to DHMC after complaining of a progressive hearing loss of 1-year duration in the left ear following administration of intravenous antibiotics and general anesthesia during surgery. Pure-tone testing at another facility suggested a moderate-to-severe hearing loss; however, an SRT of 50 dB HL and a speech recognition score of 100 percent raised some suspicions. The suspected hearing loss in the left ear was first reported after a school hearing screening test and after observations that she had hearing difficulties. Results of magnetic resonance imaging (MRI), electronystagmography, glycerol testing, and multiple blood tests were unremarkable. However, an ABR taken at that facility was reported as "consistent with a moderate-to-severe cochlear hearing loss in the left ear," though threshold ABR testing was not performed.

Figure 2A shows this patient's audiogram obtained at DHMC. Hearing sensitivity for the right ear was within normal limits, but a moderately severe hearing loss with an unusual configuration was found for the left ear. The PTA in this ear (57 dB HL) was markedly elevated relative to the SRT (15 dB HL), suggesting hearing sensitivity within normal limits. In addition, a speech recognition score of 100 percent at 35 dB HL was obtained in the left ear, also consistent with normal hearing sensitivity. The Stenger test was positive for pseudohypermucous for the frequencies 250 to 8000 Hz. Figure 2B shows TEOAEs for the left ear consistent with hearing sensitivity within normal limits for 500 Hz through 4000 Hz. Figure 2C shows an ABR waveform intensity function for the left ear. A repeatable wave V was elicited at 20 dB nHL at 9.45 msec using insert receivers. These results suggest normal hearing sensitivity between 1000 and 4000 Hz. A P300 also was obtained in this patient at low intensity levels, suggesting normal hearing sensitivity at 1000 and 2000 Hz. Upon repeated pure-tone testing, volunteered pure-tone thresholds were borderline normal, supporting the electrophysiologic results. However, the patient continued to report hearing difficulties, and it should be remembered that the ABR at another facility indicated a possible moderate sensorineural hearing loss. Therefore, a fluctuating or recovering hearing loss must be considered, although there is probably a nonorganic component.

Figure 2B Case 2: the TEOAE obtained from the left ear.
**Case 3**

Case 3 was a 31-year-old woman with a congenital, profound sensorineural hearing loss in the right ear. Serial audiograms from a referral center indicated a fluctuating hearing loss in the left ear. Multiple blood tests taken at the referral center were within normal limits with the exception of elevated cholesterol levels. She was given steroid therapy (prednisone) with no improvement in her hearing. She was then referred to DHMC for further evaluation. Figure 3A shows her voluntary audiogram. Initially, there was good agreement between the PTA and the SRT in the left ear, consistent with a severe hearing loss (77 dB HL vs 70 dB HL, respectively). However, it was highly suspicious that her speech recognition score at a +5 dB sensation level was 96 percent. A diagnostic ABR performed at that time indicated a questionable sensorineural hearing loss, although site-of-lesion results did not indicate VIIIth nerve or low brainstem involvement. Due to the diagnosis of hypercholesterolemia, the patient was encouraged to begin a low sodium and cholesterol diet. Figure 3B, which displays the ABR completed approximately 3 months later (with the patient still complaining of hearing loss), shows a large repeatable wave V at 30 dB nHL. In light of these findings, electrophysiologic measurements were expanded to include the MLR. In this patient, all components of the MLR (Na, Pa, Nb, Pb) were present and repeatable at normal latencies at 30 dB nHL (Fig. 3C). The TEOAEs were then obtained. Figure 3D shows that emissions were present from slightly above 500 Hz through 4000 Hz. The absence of a response at 500 Hz was likely due to excessive noise rather than to lack of an emission at that frequency. The overall echo level of 10.4 dB SPL
and the reproducibility value of 85 percent are consistent with normal hearing sensitivity.

Case 4

This 21-year-old woman was referred by another center after subjective complaints of decreasing hearing ability over a 3-month period. Prior to referral, audiograms indicated normal hearing sensitivity in the right ear and a mild-to-moderate hearing loss in the left ear. Pure-tone testing revealed hearing sensitivity within normal limits in the right ear, although a slightly rising configuration was noted through 3000 Hz. A mild hearing loss was found in the left ear (Fig. 4A). An MRI revealed no abnormalities. In the left ear, there was poor agreement between the PTA (43 dB HL) and the SRT (20 dB HL). Furthermore, good-to-excellent speech recognition scores were obtained at 15 dB HL (84%) and at 25 dB HL (100%). Figure 4B shows the TEOAEs for the left ear. The response spectrum and the waveform show that a cochlear response is present from 500 Hz through 4000 Hz, consistent with normal hearing sensitivity. Furthermore, a robust overall emission of 19.9 dB SPL was found, which was greater in the “poorer” ear than in the normal ear, with a reproducibility of 99 percent. Figure 4C shows the ABR, which revealed a repeatable wave V at 20 dB nHL with a latency of 8.3 msec using inserts. After being told of discrepancies in the test results, the patient’s volunteered thresholds improved to within normal limits and it was clear that pseudohypacusis behavior had occurred. This supports the fact that TEOAEs were accurate in identifying hearing sensitivity within normal limits.

This case illustrates several important points. It demonstrates that TEOAEs may be useful in identifying pseudohypacusis, even when the functional loss is reported to be in the mild hearing-loss range. It is possible that an emission could be present with the initial volunteered thresholds, but this is unlikely because of the large echo level of approximately 20 dB SPL. It is almost impossible for an echo level of this magnitude to occur if thresholds are as poor as 40 dB HL (Collet et al, 1993). It has been shown that as hearing levels become poorer, echo sizes become smaller (Prieve et al, 1993).

Case 5

This 15-year-old female patient was referred to DHMC by an otolaryngologist at another center due to inconsistent audiometric results.
patient had a history of early otitis media, myringotomies, adenoidectomy early in life, and reports of recurrent tonsillitis and sore throats (treated with amoxicillin) that had increased in frequency during the last several years. In addition, the patient reported recent hearing difficulties. An otologic evaluation revealed no significant findings. Figure 5A shows the audiogram obtained at DHMC, indicating a flat bilateral hearing loss with PTAs of 52 dB HL and 47 dB HL in the right and left ears, respectively. However, responses to speech recognition tasks were obtained at 45 dB HL, resulting in scores of 92 percent and 80 percent in the right and left ears, respectively. These results differed significantly from those obtained by the referral center. An MRI did not reveal abnormalities. Figures 5B and 5C show the TEOAEs for both ears, indicating cochlear responses just above 500 Hz through 4000 Hz that are consistent with normal hearing sensitivity. Cochlear echo levels and reproducibility values were within normal limits. Figure 5D shows repeatable wave Vs for the ABR at 20 dB nHL bilaterally, which are in agreement with emissions results.

Figures 6 and 7 show composite information for the cases reported. As a group, these patients’ TEOAEs reflect normal findings in regard to overall level and reproducibility.

DISCUSSION

These five subjects demonstrated repeatable TEOAEs, suggesting hearing sensitivity within the normal-to-borderline normal range, despite much poorer volunteered pure-tone responses. In addition, ABR responses were present at 20 dB nHL in four of five of these cases, confirming integrity of the cochlea, the auditory portion of the VIIIth cranial nerve, and the low brain stem through the lateral lemniscus. In view of these results and those of Robinette (1992), TEOAEs may be used as a quick and inexpensive screening tool for suspected pseudohypacusis. However, it is important to note that
in some cases of neural involvement, elevated pure-tone thresholds and normal TEOAEs may be obtained (Robinette, 1992).

Because OAEs are generated by the cochlea, compromise of the auditory nerve and auditory brainstem pathway will not be reflected by OAE results. Hence, the combination of results that yield normal OAEs and depressed pure-tone thresholds may not always indicate pseudohypacusis as a problem. The clinician must be aware that lesions of the auditory nerve, cochlear nucleus, and in some cases the more central pathways can result in depressed thresholds, and because the cochlea is not involved, the OAE should be present and normal. If a patient volunteers abnormal thresholds but normal OAEs, the clinician should entertain two possible causes: pseudohypacusis or retrocochlear involvement. If the patient is confronted and urged to respond better but does not, audiologic tests of neural and central integrity should be considered. Otoacoustic emissions must be used judiciously by the experienced clinician in conjunction

**Figure 5B, 5C** Case 5: the TEOAEs for the right and left ears, respectively.

**Figure 5D** Case 5: the ABR traces for the right and left ears. These ABR results were obtained with ear inserts (ER-3A).
with other clinical tools, such as the ABR. In the present study, all normal TEOAEs showed agreement with ABRs and in some cases with MLR and P300 measures.

In case 5, a full audiogram was not completed before administering an OAE. In this case, pseudohypacusis was considered as a possibility before the pure-tone evaluation was completed; thus, a TEOAE test was performed before the pure-tone evaluation was completed. This decision was made because it is easy to perform this test at the first suspicion of pseudohypacusis, since the administration of a TEOAE test takes less than 5 minutes per ear.

It is also important to note that nothing in any patient’s history suggested pseudohypacusis. Pseudohypacusis was suspected when discrepancies emerged in the basic audiologic battery. Although some of these patients had a history of medical factors that could produce hearing loss, the results strongly suggested pseudohypacusis. This underscores the need for the clinician to be alert to inaccurate test results. The reasons for exhibiting pseudohypacusis are complex and extend beyond compensation purposes. Of interest is that these subjects were all quite young, with three between the ages of 10 and 17 years.

Finally, it must be noted that TEOAEs may not be highly frequency-specific with regard to hearing sensitivity (Vedantam and Musiek, 1991; Collet et al., 1993; Hurley and Musiek, 1994). However, the major problem appears to be with false-positive identification of hearing loss rather than with false-negative identification. The TEOAEs are often inaccurate due to the absence of an emission at a certain frequency, even when hearing sensitivity is within normal limits at that frequency (Prieve et al., 1993). Therefore, the presence of an emission obtained with IL088 or IL092 with volunteered thresholds greater than approximately 30 dB HL suggests pseudohypacusis or a neural basis for the hearing loss.

REFERENCES


