Middle Ear and Inner Ear Effects on Clinical Bone-Conduction Threshold

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Abstract

The measurement of bone-conduction thresholds is an integral part of audiologic evaluation. The relationship between bone-conduction and air-conduction thresholds is the differentiating diagnostic indicator between conductive and sensorineural hearing loss. At the same time, the influence of middle ear and inner ear structures upon the bone-conduction response has been well documented. We present two cases illustrating this influence and attempt to explain the clinical bone-conduction thresholds with operative findings.

Key Words: Bone conduction, middle ear, otosclerosis

The measurement of bone-conduction thresholds is basic to audiologic evaluation. It is the relationship between bone-conduction and air-conduction thresholds that has long been considered the distinguishing characteristic of conductive versus sensorineural hearing loss (Tonndorf, 1964).

Another component of the basic audiologic evaluation is that of speech audiometry. In particular, absence of a significant air-bone gap with a concomitant reduction in word recognition score is likely to result in a diagnosis of sensorineural hearing loss.

We present two cases that apparently contradict the two basic principles mentioned above. They serve to illustrate the influences upon clinical bone-conduction thresholds that are related to both middle ear and inner ear function.

CASE REPORTS

Case 1

This 38-year-old woman was referred with a history of rapidly progressive hearing loss in the left ear over a 2-month period. During that period, she had also experienced episodes of true vertigo, including a 1-week hospitalization with upper respiratory viral infection and vertigo. The patient’s history was also significant in that she had undergone a successful left stapedectomy 15 months earlier.

Figure 1 illustrates this patient’s audiogram 1 month following a left stapedectomy. As can be seen, she exhibited normal hearing through 2000 Hz with excellent word recognition ability.

On the day of her evaluation for the rapidly progressing hearing loss, we obtained the audiogram illustrated in Figure 2. The hearing in the left ear was characterized by decreased air- and bone-conduction thresholds, with minimal air-bone gaps. In addition, the word recognition score for the left ear was significantly reduced from the test reflected in Figure 1. Tympanometry reflected an extremely mobile middle ear system on the left with normal mobility on the right, as shown in Figure 3. Acoustic reflexes were absent bilaterally for ipsilateral and contralateral stimulation, consistent with the patient’s previous diagnosis of bilateral otosclerosis.

Exploration of the left middle ear revealed necrosis of the tip of the incus along with displacement of the tip of the platinum teflon cup prosthesis away from the center of the lining membrane of the vestibule. The prosthesis was replaced with a properly placed, large-headed malleus teflon piston.

Figure 4 shows the audiogram obtained 1 month following the revised left stapedectomy.
Both air- and bone-conduction thresholds improved markedly. Moreover, the word recognition score for the left ear returned to a value similar to that recorded prior to the patient's rapidly progressing hearing loss.

Case 2

This 39-year-old female presented initially with a diagnosis of otosclerosis. She subsequently underwent a left stapedectomy and, at
1 month postoperative evaluation, the air-bone gaps in the left ear had closed to within 10 dB.

Approximately 4 months later, she returned with complaints of a rapid decrease in hearing accompanied by tinnitus and fullness in the left ear. She also complained of dizziness for the past 2 days. She related the onset of symptoms to swimming the previous week, when she flipped over backward in the deep end of the swimming pool.

As shown in Figure 5, the patient exhibited a marked hearing loss for air- and bone-conduction. While significant air-bone gaps were present, the average bone-conduction threshold had dropped to approximately 50 dB through 2000 Hz. In addition, the word recognition score was reduced to 44 percent, compared to the word recognition score of 92 percent obtained 1 month following her initial stapedectomy. Figure 6 shows the left tympanogram obtained on the same date.

Transtympanic electrocholeography (ECochG) was carried out in the left ear using clicks and tonebursts at 500, 1000, and 2000 Hz. The results are illustrated in Figure 7 and reflect an elevated negative summating potential (SP) for clicks and tonebursts. ECochG is one of the group of auditory evoked potentials useful in describing auditory function. ECochG is particularly useful in the diagnosis of Meniere's disease. An enlargement of the negative SP is generally felt to reflect endolymphatic hydrops (Gibson, 1991; Orchik et al, 1993). The procedure for measurement of the negative SP, as shown in Figure 7, has been described previously (Orchik et al, 1993).

Exploration of the left middle ear 1 week later revealed adhesions around the lower end of the platinum teflon cup prosthesis suggestive of traumatic perilymph fistula. The adhesions were removed, as well as the prosthesis. No leak was observed. A new platinum teflon cup was placed, and the patient's symptoms improved.

Figure 5 Presenting audiogram (HL in dB re ANSI, 1989) for case 2, 1 week following onset of symptoms. Word recognition score = 44 percent.

Figure 6 Left tympanogram for case 2.

Figure 7 Transtympanic ECochG for case 2 performed following audiogram shown in Figure 4.
The two cases presented here illustrate the marked effect upon the bone-conduction response, which can result when the inertial responses of the ossicular chain and inner ear fluids or the compressional responses of the inner ear structures are altered. The distortion introduced by these changes can evidently influence the word recognition score as well. In case 1, the preoperative word recognition score was obtained at a sensation level of 35 dB (85 dB HL). In case 2, the word recognition score was obtained at a sensation level of 30 dB (100 dB HL). While performance-intensity functions were not obtained, the reduced word recognition scores cannot be explained on the basis of insufficient sensation levels.

In case 1, the previously placed prosthesis had been displaced away from the center of the lining membrane of the oval window. Conceivably, this may have influenced both inertial and compressional components to the bone-conduction response. The shifting of the prosthesis would have influenced the inertial response of the ossicular chain. At the same time, the displacement of the prosthesis away from the center of the oval window membrane could have reduced the stiffness at the oval window relative to the round window, thus affecting compressional bone-conduction responses. Tonndorf and Tabor (1962) produced elevations in bone-conduction thresholds in cats by removing the stapes superstructure but leaving the footplate intact in the oval window. They hypothesized that a mobile oval window with a footplate not in contact with the ossicular chain acts as a shunt to the buildup of intracochlear pressure in compressional bone conduction. Replacement of the prosthesis in case 1 restored the continuity of the ossicular chain and the lining membrane of the vestibule.

Figure 8 illustrates the audiogram obtained at an evaluation completed 3 months after the revision stapedectomy. Both air- and bone-conduction thresholds improved dramatically, as did the word recognition score. Interestingly, this patient now had a normal SP to clicks and tonebursts by transtympanic ECochG, as shown in Figure 9.

**DISCUSSION**

The measurement of bone-conduction thresholds is basic to clinical audiology. Tonndorf (1972) has suggested that at least three major mechanisms contribute to the total bone-conduction response: (1) the reception of sound energy radiated into the external auditory canal; (2) the inertial response of the ossicular chain and inner ear fluids; and (3) the compressional response, which is the product of distortional vibrations of the cochlear shell. Changes in the above mechanisms have been shown to influence the bone-conduction response in animals and humans. Clinically, the influences can take the form of either an improvement (the occlusion effect) (Elpern and Naunton, 1963; Studebaker, 1967) or reduction (Carhart’s notch) (Carhart, 1950) in bone-conduction sensitivity.

![Figure 9 Transtympanic ECochG for case 2 performed following the audiogram shown in Figure 8.](image)

![Figure 8 Audiogram (HL in dB re ANSI, 1989) for case 2 following revision stapedectomy for the left ear. Word recognition score = 96 percent.](image)

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chain as well as the pressure gradient between the oval and round windows, with resultant improvement in the bone-conduction response.

In case 2, the bone-conduction response was also influenced by the shifting of a previously placed prosthesis. In addition, however, the operative findings of fibrous adhesions around the lower tip of the platinum teflon cup prosthesis suggest that an oval window fistula was also contributing to the reduced bone-conduction response.

The fistula would produce a perilymphatic hypotension that would be reflected as a relative endolymphatic hydrops, as indicated by the enlarged negative SP observed through ECochG (Gibson, 1992). The fistula should also have a shunting effect for the compressional bone-conduction response, as described by Tonndorf and Tabor (1962).

From a diagnostic standpoint, several factors in each case served to increase the likelihood that the apparent sensorineural component to the hearing loss might represent mechanical effects on the bone-conduction response. Both individuals had a history of rapidly progressing hearing loss and previous middle ear reconstructive surgery involving the ossicular chain. These factors raised the distinct possibility of a structural change in the middle ear as a possible cause.

Moreover, in case 1, the extremely hypermobile tympanogram in the involved ear, when viewed in the light of other history information, added to the picture of a possible mechanical change. In case 2, the added coincidence of a physical event, flipping backward in the swimming pool, with the onset of symptoms also raised our suspicion. The elevated negative SP in case 2, in the absence of any previous indication of endolympathic hydrops, indicates that ECochG may be useful in identifying the kind of middle ear anomaly found in these two individuals, especially since the postoperative ECochG was normal. Unfortunately, ECochG was not completed in case 1, so the utility of ECochG in identifying individuals with reduced bone-conduction sensitivity related to middle and inner ear mechanical changes awaits further clarification.

Hall et al (1993) have recently described a number of conditions that produce what they termed dynamic sensorineural hearing loss, or sensorineural hearing loss that responds to medical or surgical intervention. These same conditions, according to the authors, may become worse without treatment. The authors stress the importance of careful audiologic evaluation and the need for prompt otologic referral in cases amenable to treatment. The two cases presented here underscore the opinions expressed by Hall and make the point that what appears to be sensorineural hearing loss may not always be.

REFERENCES


