Clinical and Communication Access through Amplification for a Medical Student with Severe Hearing Loss: Case Report

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Abstract
This case report focuses on the communication difficulties of a 21-year-old medical student with severe-to-profound sensorineural hearing loss. The greatest difficulties reported by the patient were for stethoscope use and slide presentations in darkened rooms. Successful audiologic management was accomplished for this patient via use of a behind-the-ear (BTE) FM system for classroom use and a “homemade” amplified stethoscope that enabled him to hear diagnostic heart sounds for clinical use. The amplified stethoscope provided greater low-frequency gain for this patient than was available through other commercial units.

Key Words: FM system, hearing aid, hearing loss, stethoscope

This case presented several interesting challenges for the evaluation and fitting of a hearing aid on an individual with severe-to-profound hearing loss. At the outset, less research has focused on the “optimal” insertion gain requirements for this magnitude of hearing impairment than for people with mild and moderate hearing losses (Libby, 1986; Schwartz et al., 1988; Byrne et al., 1991). In addition, because this patient was a first-year medical student, he required amplification under some relatively demanding listening situations, and he also had been unable to use a stethoscope effectively. The problem of effective use of a stethoscope had also been a frequent concern of other hearing-impaired medical personnel seen in our clinic. The following case represents efforts over several months to provide this individual with the amplification necessary to allow him to achieve his professional goals without undue burden.

CASE REPORT

Subject

The patient, a 21-year-old male, reported to the Otorhinolaryngology Department at the Mayo Clinic in the fall of 1991 for a routine examination prior to beginning studies at the Mayo School of Medicine. He had previously been diagnosed with hearing loss at 3 years of age, as a result of mumps and chickenpox. No family history of hearing impairment was reported, and the patient denied tinnitus or vertigo. He had worn amplification subsequent to the diagnosis of hearing loss; presently, he was wearing a Viennatone AO PPII behind-the-ear (BTE) hearing aid in his left ear. He had previously tried (and rejected) binaural and BICROS amplification.

The patient reported that he communicated well under most listening situations when auditory and visual cues were available, but the two most difficult situations for him were: (1) stethoscope use, which was impossible with his hearing aid; and (2) classroom instruction with the lights dimmed, during slide or film presentations.

Audiometric Findings

Audiometric evaluation revealed asymmetric bilateral sensorineural hearing loss, with
Figure 1 Audiologic data, revealing bilateral asymmetric sensorineural hearing loss.

Profound hearing loss in the right ear and 0 percent speech recognition for stimuli presented at any sensation level. Thresholds from the left ear indicated severe-to-profound hearing loss, with a speech-recognition threshold (SRT) of 78 dB HL and a speech-recognition score of 60 percent for recorded monosyllabic words (CID W-22) presented at 20 dB SL (Fig. 1). Acoustic reflexes were consistent with cochlear pathology, as suggested by levels within 90th percentile levels as a function of hearing loss (Silman and Gelfand, 1981). The only bone-conduction thresholds measured (due to equipment limitations) were at 250 and 500 Hz and were reported by the patient to be tactile responses.

Real-ear measurements of the patient's Viennatone AO PPII BTE hearing aid at "use gain" revealed approximately 50 dB of insertion gain for the frequency region from 250 to 1200 Hz, with gain decreasing above 1200 Hz at a rate of 15 dB per octave (Fig. 2). These measurements were made with the composite noise signal of a Fonix™ 6500 Quick Probe™ test system presented at 65 dB SPL. Insertion gain results matched "Prescription of Gain/Output (POGO) of Hearing Aids" prescriptive thresholds (McCandless and Lyregaard, 1983) more closely than either Berger (Berger et al, 1989) or National Acoustics Laboratories' (NAL) target values (Byrne and Dillon, 1986), but all prescriptive formulae underestimated the actual low-frequency gain preferred by the patient. Recently, Byrne et al (1991) recommended that the NAL prescriptive formula, which is essentially a modification of the half-gain rule, be revised to recommend two-thirds gain for persons with hearing loss greater than 60 dB HL. Even if this rule had been applied, the use-gain setting preferred by the patient exceeded that of all prescriptive targets, and efforts to decrease low-frequency gain decreased user satisfaction considerably. The reduced high-frequency gain relative to prescriptive targets is understandable, because this prevented feedback from occurring at use gain, and also it is unlikely that speech audibility could be achieved without discomfort for frequencies above 1500 Hz.

Aided real-ear saturation response (RESR) measurements made with 90 dB SPL composite noise revealed that the hearing aid's peak sound pressure level approached 140 dB at 900 Hz (Fig. 3). No discomfort was reported by the patient for composite noise, narrow-band noise centered at 1000 Hz, or recorded environmental sounds (Volume 2, Tracks 21, 22, 35, and 51) from a commercially available compact disk (Jelonek, 1990), all presented in the sound field.
at 90 dB SPL from a loudspeaker positioned 1 meter distant from the subject at 45 degrees azimuth. Two-cc coupler measurements of hearing aid input/output function at use gain indicated that the hearing aid provided linear amplification for composite noise inputs below 80 dB SPL.

**BTE FM System**

The patient reported that his most difficult communication situation was in classroom settings, where the lights would frequently be dimmed for slide presentations. Typically, discussion would be limited to a single lecturer, but the reverberant conditions in the room and the lack of visual cues placed him at a considerable disadvantage for communication.

The patient had tried FM classroom amplification in the past, but was reluctant to use these devices because (1) they were never matched well to the frequency response of his personal hearing aid; and (2) he did not prefer to wear body-aid amplification systems for cosmetic and performance reasons.

At the time of this patient's initial visit, the prototype of a BTE FM hearing-aid system (Extend-Ear™) had been introduced by AVR Communications. Purchase of this device for the patient was arranged through the Mayo Medical School. The Extend-Ear™ uses an integrated FM-receiver hearing aid that is similar in size to other high-power BTE hearing aids. The transmitter is a body-aid-sized device with an omnidirectional lapel electret microphone that also serves as the antenna. The hearing aid may be used for FM-only, hearing-aid-only, or combined FM/hearing-aid applications.

Two potentiometers were adjusted to fine-tune the BTE receiver's frequency response and output to match the hearing-aid-only insertion response of the Extend-Ear™ to that of the Viennatone for 65 dB SPL composite noise (Fig. 4).

Another useful feature of the Extend-Ear™ device is that the transmitter contains both volume and tone controls, to allow adjustment of the FM signal relative to the hearing-aid signal for combined modes. Figure 5 shows the effects of varying only the user-controlled tone wheel from maximum (dotted line) to minimum (solid line) values.

After final adjustments were made to provide a close match to real-ear insertion response (REIR) and RESR measures made with the patient's personal hearing aid, he was instructed to wear the Extend-Ear™ device for classroom and leisure use for a period of 1 week.

**Observations**

The patient returned after a 1-week trial with the BTE FM system and reported that it was very helpful for numerous listening environments. He reported the sound quality to be very similar to his personal hearing aid, and the signal-to-noise ratio, when worn on FM-only setting, was improved substantially over his conventional hearing aid for lecture situations. Overall, he was extremely satisfied with the performance and cosmetic benefits over other FM systems that he had tried previously, although the rather "square" design of the BTE case caused some mild discomfort to his pinna after several hours of continuous use.

Some of the comments made by the patient...
were similar to those made by users of other FM systems, including the inability to hear environmental sounds when worn in the FM-only mode. In addition, because this unit is a wide-band system, the operating range was limited when compared to narrow-band systems. The patient reported a maximum transmission range of approximately 50 feet, after which intense static interference quickly eliminated the benefits of FM transmission. Another problem was that static interference resulted when the microphone/antenna cable became looped; this problem was solved by insulating the cable with a piece of rubber tubing over its 2-foot length.

Perhaps the greatest difficulty that the patient experienced with the Extend-Ear™ is the lack of a telecoil switch. Because of the magnitude of his hearing loss, he relies heavily on the telecoil of his Viennatone BTE for telephone conversation. Although the FM transmitter can be used to pick up the signal from the telephone receiver, the procedure necessary to accomplish this is quite awkward and not very practical. It would be helpful if future versions of this device incorporated a telecoil.

Amplified Stethoscope

Overall, the FM BTE provided a solution to this patient's difficulty in communicating in classroom settings, but not for using a stethoscope. The patient had previously tried amplified stethoscopes without success, due to problems related to distortion and feedback. One option was to interface the output of a commercially available amplifying stethoscope (Starkey ST3) to the auxiliary input of the FM transmitter, but the sound quality was still determined to be inadequate for monitoring the necessary cardiovascular landmarks.

The typical frequency response for a Littmann cardiology stethoscope, which is in widespread use by medical personnel, shows a pronounced low-frequency peak at approximately 75 to 125 Hz when measured in the 2-cc coupler (Fig. 6). Furthermore, Figure 6 indicates that the information necessary for auscultation diagnosis is primarily low frequency in nature; this does not include high-frequency information required for diagnosing some lung sounds. Figure 7 shows the frequency response of the Starkey ST3 amplified stethoscope, which uses the Littmann Classic diaphragm, as measured on the 2-cc coupler for 65 dB SPL of composite noise. The measurements suggest that maximum coupler gain was approximately 55 dB (at 800 Hz), but only about 25 dB of gain was provided for frequencies below 250 Hz. The ST3 offers no trimpots for adjustment of the stethoscope's frequency response or maximum output.

Because of a lack of commercially available options for amplified stethoscope use, a "homemade" stethoscope was built that would better compensate for the patient's degree and configuration of hearing loss. A standard Littmann Classic stethoscope was modified, using an in-the-ear faceplate (Siemens LSI PP2) containing twin BK receivers (3021) mounted on the housing of an amplified stethoscope (Starkey ST3). This arrangement provided greater low-frequency gain than the commercial unit and incorporated an adjustable tone control, providing 46 dB of gain at 500 Hz. Furthermore, the circuit was mounted closer to the diaphragm head (Fig. 8) than for the Starkey ST3 amplified scope (Fig. 9), in an effort to minimize acoustic feedback. Figures 10A and 10B show the frequency response and input/output function, respectively, for the "homemade" manufactured device measured in the 2-cc coupler.
Observations

The patient has been using the "homemade" amplified stethoscope successfully for several months. His medical school professors have listened to the stethoscope and report that it provides a reasonably faithful reproduction of sounds necessary for auscultation diagnosis. The patient's primary complaints are related to convenience; for example, because an in-the-ear faceplate was used, size 13 batteries were used, which are incompatible with the 675 cell used by both the Viennatone and Extend-Ear\textsuperscript{TM} hearing aids. The patient, however, has adapted to carrying an extra set of 13 and 675 batteries, in the event that either amplifying device fails.

CONCLUSIONS

For persons with mild or moderate hearing loss, conventional amplified stethoscopes or deep-fitting hearing aids may provide a viable solution to auscultation diagnosis. For persons with severe-to-profound hearing loss, however, one solution may be to custom design a stethoscope to provide selective amplification and output that is appropriate for their hearing loss without producing acoustic feedback.

The subject of this case report has benefitted from both the FM hearing-aid system and the "homemade" amplified stethoscope. It is unclear whether these devices will enable him to specialize in a medical area requiring acoustic monitoring of subtle chest or heart sounds, but they provide a reasonable solution at the present time for someone with his degree of hearing loss. Perhaps emerging technology will provide more sophisticated signal processing and audiovisual data analysis.

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REFERENCES


