The Use of Impedance Measures in Hearing Aid Evaluation

GEARY A. McCANDLESS, Ph.D.
Professor, Dept. of Communication
and Head, Audiology
University of Utah Medical Center

Although not ordinarily used in the hearing aid selection process, impedance measures are as important clinically as pure tone and speech audiometric tests in assessing the integrity of the auditory system prior to the actual hearing aid fitting. Impedance measures play an important part in the process of hearing aid evaluation and selection processes since they can be used to identify patients who have middle ear problems for referral which may be treated by medical or surgical means. Tympanometric measures have been particularly helpful in clinical measurement of middle ear pressures, tympanic membrane mobility and in assessing the presence and severity of otitis media. Acoustic reflex measures probably have more direct utility in assessing auditory function relative to hearing aid fitting since these reflexes can be used to validate the presence of sensorineural hearing loss. The acoustic reflex is especially helpful in describing the loudness recruitment function and also assessing VIII nerve function.

The many imprecisions in hearing aid procedures has caused clinicians to be alert to any procedure which has prospects of adding objectivity to the selection process. It is reasonable, therefore, that impedance techniques are now being viewed in hopes they may add not only accuracy, but may also serve to better describe how the pathological ear functions both with and without amplification. Their special value, however, lies in the fact that they do not rely on the subjective reactions of the patient as do the conventional selection techniques which employ linguistically based test materials.

While at present it is impossible to predict the ultimate value of impedance measures in hearing aid selection, attempts have been made recently to employ these tests in hearing aid evaluations, specifically in determining output, gain and frequency response requirements of hearing aids. At the present time, impedance measures are utilized primarily for the special clinical case's use. Whether or not impedance is to be integrated into the routine evaluation process remains to be seen.

It has long been recognized that in the process of determining specific electroacoustic characteristics it is essential to select an instrument which has sufficient gain to compensate for the hearing loss, yet which has an output limited to keep amplified sounds below an uncomfortable level. Further, it is well accepted that a frequency response should be selected which produces maximum clarity for the individual patient. While there seems to be general agreement that these characteristics are important, there is not any real consensus as to how these parameters should be measured nor how to determine the efficacy of specific fittings once selected. This has led to great subjectivity and imprecision in the selection process.

At the present time, impedance measures have assisted in three areas: 1) in determining the optimum desired electroacoustic characteristics including determination of saturation sound pressure level, 2) in evaluating or comparing the function of various aids using non-verbal technique, and 3) in setting the real ear gain in children who are unable to manipulate the volume control. Examples of these will be given following discussion.

DETERMINING USE GAIN BY IMPEDANCE MEASURES

The primary objective of any hearing aid is to help overcome through amplification the loss of hearing sensitivity imposed by hearing impairment. Clinicians, therefore, would agree that although gain is a most important electroacoustic ingredient, there appears to be no universally accepted technique for determining the optimum gain. In actual practice, the gain is set by the patient at a level which he feels is subjectively comfortable; however, the volume control is often found to be set anywhere between 1/8 and full volume.

Although it is relatively easy to measure gain electroacoustically, there may be little relationship between the gain as measured in hearing aid test box and use gain or real ear gain as experienced by the user because of the pathological growth of loudness found in sensory hearing loss. We are not yet quite able to accurately predict the effects of the tube and other acoustic coupling on the frequency response or gain of the instrument. It is important, therefore, to obtain some more objective measure of gain while the subject is wearing the hearing aid plus the tubes, molds and other accoutrema.

One technique for determining real ear gain has been described by Tonisson, (1975) who measured the difference between the aided and unaided reflex thresholds. In those cases where the acoustic reflex is present, this measurement is fairly easily derived by placing the impedance probe in the ear contralateral to the ear on which the hearing aid is worn. Narrow noise bands, wave trains, or calibrated warble tones are presented free field and the acoustic reflex is obtained for various frequencies between about 300 and 4000 Hz. The difference between the aided and unaided reflex threshold as illustrated in Fig. 1 is the real ear or use gain at a particular volume control setting and is displayed in SPL. As the volume control is raised or lowered, aided reflex threshold changes correspondingly, and thus the gain will be altered.

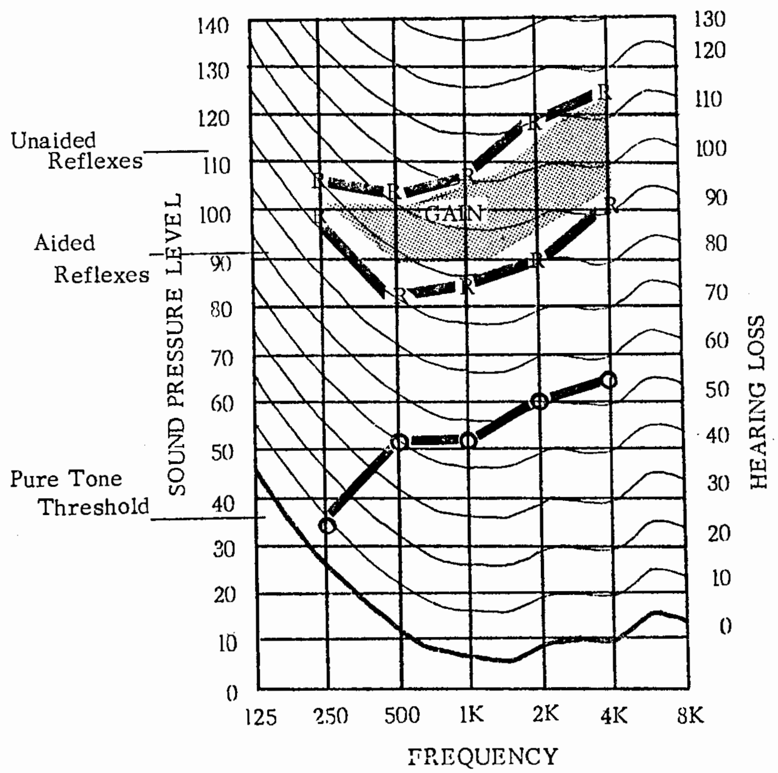

Fig. 1. Unaided and aided acoustic reflex threshold expressed in sound pressure level. re: .0002 dines per cm^2. The difference between the aided and unaided threshold gives the real-ear gain of the hearing aid.

The use of the acoustic reflex to adjust the use gain in hearing aids in children has been quite successful, (McCandless, 1975). For many years when hearing aids were placed on children, the volume control has been set at an arbitrary level which in many cases has been totally inappropriate for the child's needs. By placing the hearing aid on a child and measuring the acoustic reflex in the contralateral ear with a 65 dB SPL speech input, the volume control can be lowered or raised until the reflex is barely observed. The optimum setting can be made by setting the volume control at a level just below the occurrence of the acoustic reflex gain to conversational speech as shown in Fig. 2.

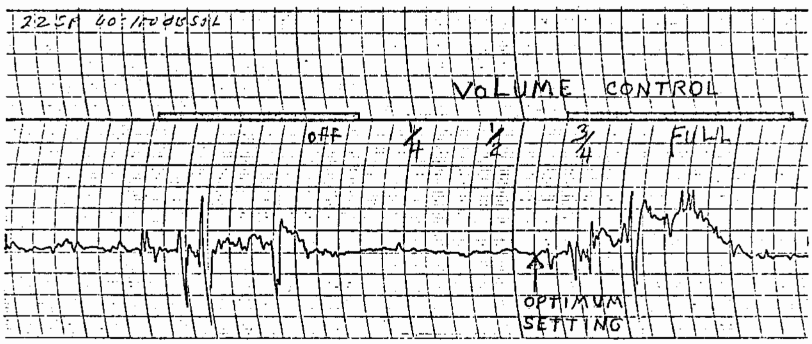

Fig. 2. Setting the volume control using acoustic reflexes. The volume control is set at a level just below a point where the acoustic reflex is elicited with a 65 dB SPL speech input to the hearing aid.

DETERMINATION OF AIDED FREQUENCY RESPONSE USING IMPEDANCE MEASURES

It is essential to shape the frequency response in order to optimize the intelligibility of the patient and to minimize low frequency noise. Although at the present time there is considerable disagreement as to what constitutes the optimum frequency response for certain hearing losses, there does appear to be some general agreement that some frequency compensation should be made for those frequencies that have greatest hearing loss.

Impedance measures may be of considerable benefit, especially in children, in determining the real ear frequency response. This technique is much more precise that making inferences about frequence response based on test box results. A real ear frequency response measurement is made by obtaining the acoustic reflex in the ear contralateral to the hearing aid. Acoustic reflex thresholds are compared for pure tones, narrow bands, and/or damped wave trains. Fig. 3 illustrates the differences in the real ear frequency response between two hearing aids using the technique (Snow and McCandless, 1976).

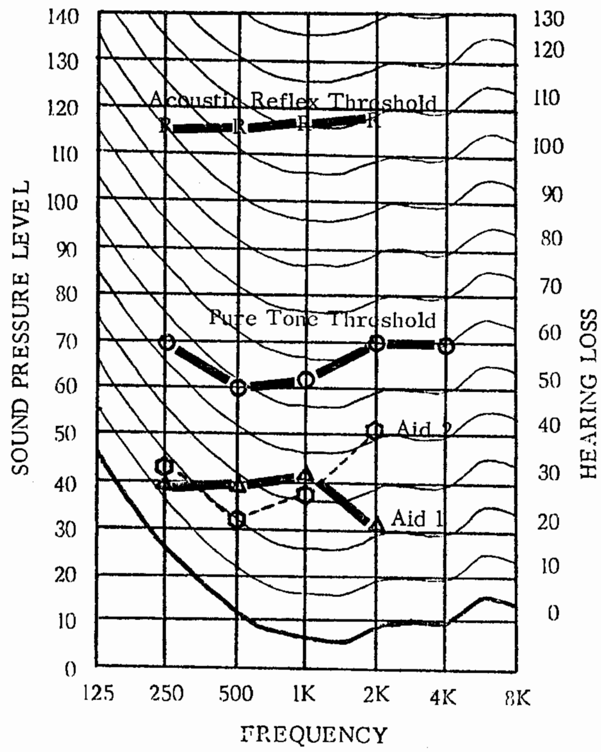

Fig. 3. Example of the real-ear difference in the frequency response of two hearing aids using the acoustic reflex.

DETERMINING SATURATION SOUND PRESSURE LEVEL USING IMPEDANCE MEASURES

For over 30 years it has been assumed that the upper usable hearing level extends to the point where sounds become painful. In most ears, this is between 125 and 135 dB SPL. In 1966, Hood and Pool (1966) found that the functional level of comfortable loudness extended only to about 108 to 110 dB SPL for pure tones in normal ears and ears with cochlear pathology. Further, they suggested that stimulation above these levels for any length of time may cause significant temporary threshold shifts. McCandless and Miller (1972) found there was a close correlation between the acoustic reflex threshold and the point of beginning discomfort as described by Hood and Pool. These studies suggest that since the thresholds of discomfort are the same or only slightly elevated above the levels of the normal ear, that hearing aids with outputs of 115 to 135 dB very often produce excessive sound pressure to the pathologic ear.

Therefore, it is important to determine for each patient his upper usable limit of hearing and to provide an instrument which limits the sound pressure below this point of discomfort. If these levels are exceeded for any length of time, not only is there temporary threshold shift but the acoustic reflex goes into tonic contraction, a condition which is not accepted by the hearing aid user.

Although in cooperative patients, the point of overload can be accurately determined by obtaining a point of beginning discomfort, an accurate point of overload can also be determined using the acoustic reflex threshold. This is done by introducing speech, pure tones, or narrow band stimuli through an audiometer ear phone while the impedance probe is in the contralateral ear. Reflex thresholds are determined and the levels at which those are obtained can be converted to sound pressure shown in Fig. 4. Shown on this figure are the pure tone thresholds which are converted to sound pressure units. The distance

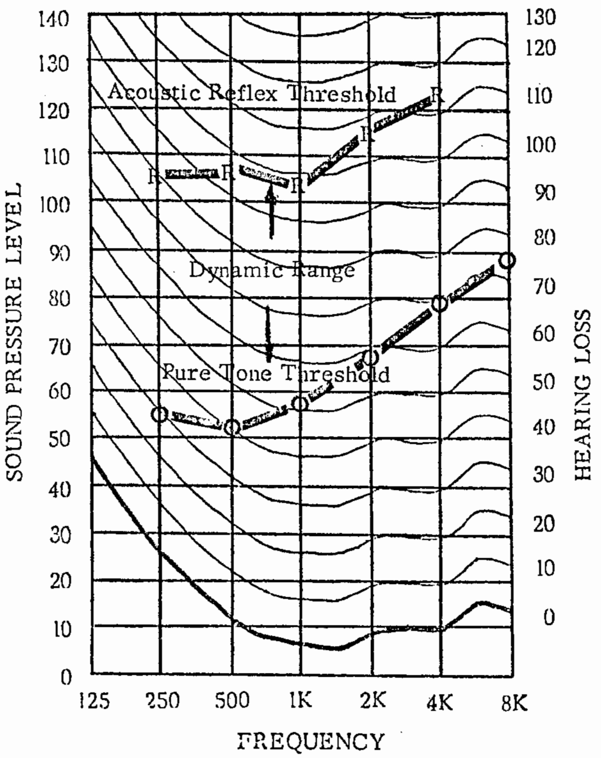

Fig. 4. The dynamic range of hearing is illustrated on a sound pressure chart as the range between the pure-tone threshold and acoustic reflex threshold.

between the reflex thresholds and the pure tone thresholds is the subject's dynamic range. The SSPL to be recommended in a hearing aid is simply the average discomfort threshold at 500, 1000, and 2000 Hz.

The impedance technique can also be utilized in determining whether or not a specific hearing aid being tested produces excessive sound pressure levels. This is done by placing a hearing aid on a subject with the impedance probe in the contralateral ear to the hearing aid or the master aid. Calibrated signals are introduced free field at levels corresponding to average environmental sounds such as speech at 65 dB SPL. By observing the change in impedance to speech, one can determine if the ear is being overloaded if the acoustic reflex is seen to contract to normal environmental sounds. The SSPL can be modified in specific aids to keep these sounds below the points in which the middle ear muscles stay in constant contraction.

DISCUSSION

At the present time, the use of impedance measures seem to have greatest value in patients who are unable to give subjective response. The use of these measures, however, should not necessarily be limited to children or difficult-to-test subjects, because they have a decided advantage of providing objective data related to the ear that does not depend upon the often variable subjective responses. Further, these responses are extremely stable over long periods of time and can serve as a reference for all patients to determine, 1) if the ear is being overloaded with a hearing aid, 2) if a desired needed frequency response is obtained, 3) if the gain is set at an optimum level, and 4) if changes in the hearing aid function occur over time.

Since impedance measures, especially the acoustic reflex, constitute a physiological rather than subjective response, and if these measures can be related in the future to criteria of user success, they should prove valuable in the hearing aid selection process. Further, they have the added advantage that the above test can be performed in minutes and at least can be used to approximate the electroacoustic characteristics best suited for a particular patient. One can then apply linguistic tests to determine aided function with speech materials. Impedance techniques can be employed to test aids differentially; can be used with master hearing aids, can be used to prescribe specific electroacoustic characteristics even without testing individual hearing aids, and can be used to objectively set the frequency response and gain setting. While much research remains to be done regarding the refinement and use of such techniques, the fact that this can be applied even to a child asleep under sedation as well as having many other applications certainly makes future applications attractive.

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