Paparella: Volume II: Otology and Neuro-Otology

Section 3: Diseases of the Ear

Part 1: General Problems

Chapter 16: Functional Hearing Loss

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A medical search conducted on the topic of functional hearing loss revealed only eight articles in English since the publication of the second edition of this book. It appears, therefore, that functional hearing loss is no longer the issue that it was 20 to 30 years ago, when functional hearing loss related to military service was the largest percentage described in the literature. Discussions with colleagues in Veterans' Administration hospitals suggest that Vietnam era veterans for some reason do not manifest functional hearing loss as often as those as veterans of the Korean and World Wars. Furthermore, physiologic measures of auditory function are readily available. Comparison of behavioral thresholds with such physiologic results quickly exposes inconsistent patterns. However, it must be remembered that the common understanding of the word "hearing" is not exactly what is measured by physiologic tests. For that reason, we must consider a definition of hearing before presenting a definition of functional hearing loss.

Hearing can be defined in two distinctly different ways. The conventional definition uses behavioral responses to auditory events. Responses are a function of the condition of the auditory system, understanding of the task, and willingness to cooperate, in addition to physical and physiologic parameters. The advantage of such responses is that a number of auditory capabilities may be explored, from threshold sensitivity to discrimination of complex signals. The disadvantage of such responses is that they rely on the patient's cooperation, the factor absent in functional hearing loss. Alternatively, hearing may be gauged by physiologic measures. They require no cooperation beyond being physically still and, therefore, present a distinct advantage. Their disadvantage is that they are limited to measures of sensitivity that often correlate poorly with audiograms. As an extreme example, consider the patient with an absent acoustic reflex in the presence of a normal audiogram - a rare situation but not unheard of. Conversely, there are reports of normal physiologic nerve VIII responses in the absence of any consistent auditory behavior (Cullen et al, 1976). In many cases, the distinction between behavioral and physiologic responses need not be made. Even so, the physician would do well to keep both definitions in mind.

From a practical point of view, functional deafness means that the pattern behavioral response is inconsistent within itself and other known information about the auditory system. This definition avoids a number of complicating factors that make other definitions less viable, such as those that include "malingering", with the implication that the patient is attempting to avoid some odious task. It avoids considerations of greed, as might be the case when financial gain may be contingent on hearing loss, and it avoids manifold psychiatric ramifications.

Behavioral Measures

Evaluation of behavioral results is based on deviations from test norms, the most fundamental being threshold responses displayed on an audiogram. If thresholds are abnormal, judgments of their validity and the likely site of lesion are made by examining additional information and comparing this information with that obtained from groups of patients with known lesions. These diagnostic patterns generally fall into the categories consistent with conductive, cochlear, retrocochlear, or cortical lesions. It is the apparent absence of a lesion that suggests that the "site" is functional.

Notice that none of the behavioral tests described below can be used to determine thresholds. Even the Stenger tests are subject to individual variation; at best they all permit conclusions similar to "Hearing is no poorer than...".

Pure-Tone and Békésy Audiometry

Although some reports suggest that certain audiometric shapes are indicative of functional hearing loss, that are not reliable indicators of functionality (Carhart, 1958; Farley et al, 1960; Fournier, 1958; Ventry and Chaiklin, 1965a). Three aspects of the audiogram can provide indications of functional hearing loss. First, in the case of asymmetric loss, the difference in unmasked thresholds obtained from the better and poorer ears should not exceed 40 to 60 dB by air conduction or 0 to 10 dB by bone conduction. These values are based on the well-documented interaural attenuation of the human skull (Chaiklin, 1967; Zwislocki, 1953, 1963). In the extreme case of no hearing in one ear and normal hearing in the other, sounds should cross over from the opposite earphone or bone conduction vibrator to the normal cochlea, producing a shadow curve (Fig. 1). This occurs because the patient is instructed to respond to any sound, however faint, and because, at threshold, localization of sound is difficult. This situation can be approximated with tuning forks. Stimulation of the mastoid on the poorer side should produce hearing, albeit from the better ear. A second indicator of functionality is test-retest variability. It should not exceed the commonly used criterion of ± 5 dB (Carhart and Jerger, 1959). Differences between thresholds obtained by ascending and descending methods should not exceed 10 dB (Harris, 1958). Those with functional hearing loss often exceed these limits because humans, in general, find it difficult to make absolute judgments of stimulus intensity. Therefore, they do not produce consistent artificially high thresholds.

Békésy audiometry can provide indiciations of functional hearing loss (Hood et al, 1964). Thresholds should approximate those obtained by conventional techniques (Harbert and Young, 1966; Reger, 1952). Several reports suggest that those with functional hearing loss will trace continuous thresholds better than interrupted thresholds, a reversal of the pattern with organic hearing loss (Jerger and Herer, 1961; Peterson, 1963; Resnick and Burke, 1962). There are reports that some subjects with normal and pathologic hearing may also reverse the tracings; therefore, reversal is not an absolute indication of functionality (Hopkinson, 1965; Price et al, 1965; Stark, 1966). Modifying standard technique by increasing the duration between pulses of the interrupted stimulus (lengthened off-time (LOT)) has been reported to increase the likelihood of reversal (Hattler, 1970; Hattler and Schuchman, 1971).

Speech Audiometry

Normal performance with speech is best understood in the context of the performance intensity (PI) function, whereby increasing levels of presentation produce increasing levels of performance. The baseline is the speech reception threshold (SRT), now more commonly termed the spondee threshold (ST), which approximates the pure-tone average (PTA) using 500, 1000, and 2000 Hx in those with relatively flat audiograms (Ventry and Chaiklin, 1965a). When the audiogram slopes sharply down to the right, the SRT is related to the better two thresholds or, in some cases, the best threshold (Fletcher, 1950). SRTs which are 10 dB better than the PTA suggest a functional hearing loss (Conn et al, 1972). A related measure is the speech detection threshold (SDT). In this task, a patient is asked to indicate each time that a word is heard rather than repeating the word. In normal individuals, the SDT is about 10 dB below the SRT (Egan, 1948). The relation between the SDT and SRT should remain constant in those with flat hearing losses. In the case of high-frequency hearing loss, the SDT is more dependent upon low-frequency hearing. Thus, although not reported in the literature, differences of less than 10 dB between the SDT and the SRT suggest a functional hearing loss.

Maximal discrimination occurs 30 to 40 dB above the SRT, depending on the test materials. In cases of sensorineural hearing loss, the PI function is displaced to the right, fails to reach 90 to 100 per cent, and is more shallow than normal. Functions steeper than normal have not been reported. Thus, the implication of high scores at low sensation levels is that degree of loss is being exaggerated (Nilo and Saunders, 1976; Gold et al, 1981).

In summary, the pattern of PTAs, SRTs, and PI functions provides the first indications of functional hearing loss. PTAs should approximate SRTs. Both should be about 10 dB greater than SDTs, and the PI function should not be steeper than normal. If there are discrepancies in the pattern, several specific tests may be considered.

Delayed Auditory Feedback

Delayed auditory feedback audiometry is a technique based on the fact that we monitor our speech production by listening to our voices and tend to follow externally imposed rhythmic patterns (Billings and Stokinger, 1975; Citron and Reddell, 1976; Hanley and Tiffany, 1954). Patients are asked to read a passage aloud while, with no forewarning, their own voices are introduced into earphones with about a 0.2-second delay. The level of the delay signal is raised until, by virtue of the unnatural echo, reading fluency is disrupted and the time needed to read a passage increases. Reading time for a practiced passage without delayed feedback is compared with reading time with various levels of delay. It is presumed that reading time increases when the delayed presentation is heard. Therefore, hearing is no poorer than the level at which reading time first increases.

A similar task using tonal stimuli begins by asking patients to tap a telegraph key in a particular rhythm. The key controls the output of a tone generator, which presents a delayed tone to the earphones. It is presumed that hearing the delayed tone disrupts the tapping rhythm. Thus, hearing is no poorer than the level of the delayed tone at which tapping is disrupted.

Lombard Test

The Lombard test is a variation on one principle applied in delayed auditory feedback (Taylor, 1949). That is, to continue monitoring vocal output, patients tend to raise their voices in the presence of noise. A microphone and sound level meter are used to measure speech level while the patient reads aloud. If the level increases when noise is introduced into their ear phones, it is presumed that the noise was heard. Normal resistance to the noise-speech level relationship is not well understood and the technique is not often used (Hopkinson, 1972).

Doerfler-Stewart Test

A third variation on the principle that auditory input affects responses is the Doerfler-Stewart test (Doerfler and Steward, 1946; Hattler and Schuchman, 1971; Ventry and Chaiklin, 1965b). In this case, noise is used disrupt whatever internal standard patients may be use to decide when to repeat words. To summarize a rather complex procedure, the patient is asked to repeat a continuing list of words at 5 dB above the initial SRT. While doing so, increasing levels of noise are mixed in until the words are masked. The level of the words is then lowered under the "cover" of the noise, and then the noise is lowered to "uncover" the words. In the process, it is hoped that the artificial reference for judging when to repeat words will be destroyed and a less inflated SRT will be obtained.

Story Tests

If functionality is suspected in unilateral or asymmetric loss, story tests may provide a demonstration of hearing from the poorer ear when its hearing level has been approximated (Hopkinson, 1972). The test involves presenting a recorded story such that the words are presented to one ear, the other, or both. The patient is then asked to repeat the story. As a simplified example, the following sequence might be presented:

Better ear: The cat was caught by the man.
Poorer ear: The fish was not caught by the old man.

If the patient tells a story about fishing, the poorer ear has heard.

Stenger Test

Another test applicable to unilateral or asymmetric loss involves the Stenger phenomenon. If two identical signals are presented to each ear and they differ in sensation level by more than about 20 dB, the signal appears to come from the ear in which the sensation level is higher. Thus, if hearing is normal and a 50 dB signal is presented to the left ear and an identical 10 dB signal is simultaneously presented to the right ear, the listener will be unaware of the 10 dB signal. If a 60 dB loss is being claimed on the left, the listener will not acknowledge the right signal. Failure to acknowledge the 10 dB signal is proof that the 50 dB signal was heard. The difference between sensation levels necessary to produce the effect may be as high as 35 dB (Taylor, 1949).

The technique may be implemented with either tones or speech (Taylor, 1949; Ventry and Chaiklin, 1965b). Since it is critical that the two signals be identical in the time of onset, phase, spectrum, and so forth and since diplacusis may be present in patients with organic hearing loss, the use of tonal stimuli may not produce a consistent indication of functional hearing loss (Johnson et al, 1956; Zwislocki, 1963). Because of the acoustic complexity of speech and the increased difficulty in detecting minor differences that might occur between ears, speech would seem to be the preferable stimulus.

Eyeblink Test

Loud auditory stimulation produces an eyeblink, a fact used as the basis for neonatal screening (Downs and Sterritt, 1964). Since both normal and hard of hearing individuals blink at approximately the same levels, the eyeblink alone is of little value in determining organic hearing, except in cases of complete failure to respond to sound (Galambos et al, 1953). However, the eyeblink can be conditioned to stimuli at near behavioral thresholds if paired with a strong light (Galloway and Butler, 1956). The conditioned eyeblink may provide an alternative to conditioning procedures using shock, since their use may not provide sufficient safety (see end of section on physiologic measures).

Lip Reading Test

Certain speech sounds can be read on the lips but may be confused with other sounds. The "b" in bat is clearly discernible as a movement from closed to open lips. It is practically identical to the movement associated with the "p" in pat. Distinguishing between the two requires auditory input. The principle that lip reading efficiency is dependent on audition has been exploited in one test for functional hearing loss (Falconer, 1966; Weiss, 1971). The test is applicable when face-to-face communication ability is greater than would be expected from the audiogram and it is attributed to lip reading. A list of words is presented with both sound and the opportunity to lip read. High scores indicate hearing, since only audition will allow the correct selection among the visually similar alternatives.

Other Indications

A patient's general demeanor and discrepancies between communication ability in test and nontest situations have been suggested as indicators of functionality. Using finger motions as responses in pure-tone audiometry, Green (1969, 1972) identified six basic categories of behavior. For present purposes "malingafingers" are of surprisingly practical value. They make themselves knownby delayed responses that occur only after long presentations. They also identify themselves by what Green called an "inflation index" - that is, increasingly higher levels of stimulation are necessary to obtain a response as the testing proceeds. Any number of reviews of functional hearing loss have included comments to the effect that a patient's nontest communication ability may be better than test results. For example, the patient who handles questions easily during the taking of the history may produce unexpectedly high SRTs. At the other extreme, functional patients may exaggerate "attempts" to hear compared with non-functional individuals with similar hearing losses. Other indices of possible functional hearing loss include using an excessively loud voice, refusing to communicate except by written messages, and better quality of speech production than would be expected from the degree and duration of supposed hearing loss.

Physiologic Measures

A second approach to the evaluation of audition is the use of physiologic indices. Unlike behavioral measures, most of the following techniques have been used to predict audiometric results. Therein lies their value, although with the exception of skin responses, predictive accuracy is not what might be hoped for.

Acoustic Reflex Thresholds

Reflex thresholds provide an indication of the likely audiogram. Figure illustrates two important features of the reflex threshold. First, it occurs at levels above behavioral thresholds; thus, the observation of a reflex is prima facia evidence that cranial nerve VIII discharged. Second, there is a relationship between behavioral and reflex thresholds. A number of investigators have developed equations predicting behavioral thresholds from acoustic reflex thresholds for tones and white, low-pass, and high-pass noises (Jerger, 1972; Jerger et al, 1974; Niemeyer and Sesterhenn, 1974). Reviews of the efficiency of the various equations suggests that errors occur, to one degree or another, ni 30 to 50 per cent of predictions (Keith, 1977; Hall and Koval, 1982; Tsappis, 1977; Van Wagoner and Goodwine, 1977). Although they do not produce precise audiograms, reflex thresholds provide a quick first step in evaluating the validity of audiograms. They are commonly obtained in routine evaluations, and the technique is easier than many of the behavioral tests mentioned above. The only limitation is that they are obscured by conductive losses.

Electrical Response Audiometry

Cortical responses are not of particular value in that context because they become less stable as patient alertness decreases and when the patient is under the influence of drugs. While VIII nerve and brain stem responses are relatively immune to such influences, the former cannot be detected at levels approximating behavioral thresholds without placing an electrode at or through the tympanic membrane. Since brain stem responses can be observed at near threshold levels with surface electrodes on the mastoid and vertex, they are the most widely used measures. Their one disadvantage lies in the acoustic stimulus necessary to evoke a response. The stimulus must be both brief and of sudden onset so as to produce a synchronous discharge in the auditory pathways. Short signals produce acoustic splashes so that it is difficult to limit the stimulus to the specific frequencies, as is done in routine audiometry.

For the commonly used click stimuli, a variety of studies have shown that the major wave (V) in the response can be followed to within 10 to 20 dB of behavioral thresholds in normal individuals for the same stimuli. It has been further demonstrated that the click stimulus is primarily correlated to behavioral thresholds in the region between 2000 and 4000 Hz. Thus, the presence of a response at normal threshold levels virtually ensures a normal auditory periphery. However, in the presence of ogranic hearing loss, inferring an audiogram becomes a problem. For example, Jerger and Mauldin (1978) reported correlations between response latency and behavioral thresholds, combinations of thresholds, and audiometric contour. The highest correlation was only .49 with 4000 Hz thresholds. (Though Jerger abnd Mauldin did not use clicks, their 3000-Hz half-cycle stimulus approximates them. Their careful study warrants review by anyone considering the use of clicks in evaluating true thresholds.) There are several alternatives to click stimuli that permit the determination of more frequency-specific thresholds. Such techniques are beyond the scope of this chapter, since they are not standardized and vary in the typical clinical setting. Stapells and associates (1985) provide an excellent summary of these alternatives. Masking portions of the cochlea that are *not* of interest is one alternative; using tonal stimuli with carefully controlled rise, duration, and fall times is another.

Initial clinical reports about two additional potentials suggest that they may provide frequency specific thresholds. Sanders (1983) obtained "slow brain stem responses" (SN_{10} with latencies of eight 15 msec) in 10 normal adults and four with sensorineural hearing loss. Using tone pips of 500, 1000, 2000, and 4000 Hz, he obtained thresholds within 10 dB of those obtained with conventional audiometry. The second reported potential is the 40-Hz sinusoidal response. Stapells and colleagues (1984) suggested that responses can be discerned "within a few decibels of behavioral thresholds" over the range of 500 to 4000 Hz; however, Lynn and coworkers (1984) suggested that differences may be as large as 30 dB at 500 Hz and 20 dB at 1000 Hz. The latter group pointed out that the 40 Hz response may *underestimate* behavioral thresholds by as much as 20 dB.

In preparing the 1980 edition of this chapter, we expected that unambiguous techniques for determining behavioral thresholds would be available by this date. This brief review indicates that such is not the case.

Skin Response Audiometry

Skin response historically have been associated with the determination of valid thresholds in functional hearing loss. The technique is known by a variety of names, such as psychogalvanic skin response audiometry, electrodermal response audiometry, and galvanic skin response audiometry. It is based upon Pavlovian conditioning model in which the bell-meat-salivation sequence is replaced by tone-shock-change in skin resistance. It is the only technique consistently reported to produce frequency-specific thresholds that approximate conventional audiometry. The wisdom of employing this technique has come into question since the publication of an electrical shock standard by an independent safety organization (UL 544, 1976). Briefly, the standard suggests that potential for iadvertent shock should not exceed 50 microamperes. The only instrument package designed for skin response audiometry permits shocks in excess of tent times that limit, and it is no longer in production. Intentional shock is used routinely in a number of medical settings and is permitted by the standard if used by "qualified medical personnel". Until a clear definition of "qualified medical personnel". Until a clear definition of "qualified" is made, we are unable to recommend the technique for routine audiologic use in spite of its thoroughly documented success in estimating behavioral thresholds (Knox, 1972) and recent clinical reports of its continued effectiveness (Stankievicz et al, 1981).

A Recommended Routine

The cursory summary presented above was dictated by the purpose of this chapter, which is to summarize the tools available, and by the fact that the otologist is unlikely to administer such tests. Nonetheless, the otologist needs some understanding of what a patient will undergo in the process of evaluating functional hearing loss. To provide that insight, we present, in these last few paragraphs, a likely sequence for the patient suspected of having functional hearing loss.

The first steps are typical of any evaluation. Because of their value in giving initial direction to a test battery, tympanometry and acoustic reflex tests are the starting place. Tympanograms form the basis of even the most cursory examination. If they do not indicate normal middle ear energy transfer, then interpretation of acoustic reflex thresholds for the purpose of estimating behavioral thresholds is not possible. In the presence of normal tympanograms, behavioral thresholds should be at least 20 dB better than acoustic reflex thresholds. Appropriate predictive equations should be used to estimate the degree of hearing loss and the slope of the audiogram.

The initial behavioral measure should be SRTs because the better SRT can be estimated from communication during the history-taking. The patient is familiarized with the test words and asked to repeat all or any part of the words heard; the earphones are placed, and the presentation is begun in the better ear, if one has been specified, at levels near normal threshold. The level of each presentation is increased in 5- to 10-dB steps until a response is obtained, at which point the SRT is determined by standard methods. The opposite ear is tested in a similar manner. The point is to reduce the likelihood of patients with functional hearing loss reestablishing any exaggerated criteria for response that they may have had or to prevent them from using an initially high level as a current criterion.

If the SRTs are unexpectedly high, SDTs should be obtained. Then the PI function should be developed for each ear starting at no more than 10 dB above the SRT. Tonal thresholds should be obtained next, beginning at 1000 Hz. These should agree with the SRTs. If not, thresholds at 500 and 2000 Hz are obtained to see if their values contribute to a better agreement. If they do not, it is unlikely that further attempts at obtaining ascending thresholds will facilitate reaching conclusions. In the absence of agreement, thresholds at 1000 Hz should be repeated while using a descending technique of presentation. They should agree with the initially obtained ascending thresholds. Failure to find agreement leads to tests for functionality.

Of the available behavioral tests, the simplest, most effective test for unilateral cases is the Stenger. Speech stimuli should be used first. For bilateral losses, delayed auditory feedback for tones and, perhaps with less efficiency, for speech would seem to be the tests of choice if the equipment is available. When the pattern of results continues to suggest functional deafness, the patient should be courteously and vaguely informed of the existence of intertest inconsistencies and just as courteously reinstructed on the superficial premise that the patient's initial instruction was incomplete or inadequate. The definition of "threshold" and its implications for the patient's responses should be emphasized and attempts made to obtain more realistic tonal thresholds. In the absence of any improvement in the patient's cooperation, either the best estimates of hearing can be reported with the clear statement that these may not represent his or her best hearing or auditory brain-stem response audiometry can be attempted.

It must be emphasized the judgment of functional hearing loss is based on the elimination of other etiologies in the presence of inconsistencies in the pattern of auditory behavior. The necessary pattern is developed through a series of tests that may or may not permit estimates of true hearing. The final "proof" of the presence and magnitude of the functional component is the obtaining of normal results or a pattern consistent with otherwise specifiable etiologies.