Audiological Aspects of the Diagnosis of Acoustic Neuromas*

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Auditory symptoms are usually the first indication of a developing acoustic neuroma. A high index of suspicion and the use of sophisticated auditory tests will frequently make it possible to diagnose this tumor at a time when it is still contained in the internal auditory canal and presents only auditory clues. The advent of microsurgical techniques for the approach to these small tumors has emphasized the diagnostic value of precise auditory testing. 5,9,10,11

The purpose of this article is to review briefly the auditory tests used in the diagnosis of acoustic neuroma. The typical test findings will be discussed and screening tests which may be performed in the general physician's office will be described.

What Are We Evaluating?

Auditory evaluation in the past has been limited to a pure tone audiogram, testing air and bone conduction. The resulting audiogram showed either a conductive or nerve type of impairment (Fig. 1). A nerve impairment was found in patients with acoustic neuroma. The audiogram was of little help in early diagnosis because there were many other conditions which could be the cause of a similar audiogram.

It became apparent, however, that there were many differences in the way a patient with an acoustic neuroma responded to speech, to loud tones, and to prolonged stimulation of soft tones. These differences were correlated with the clinical picture and began to show a typical pattern. Patients whose nerve impairment was due to a cochlear disorder such as Menière's disease showed one type of pattern, whereas those with a true nerve or retrocochlear lesions such as an acoustic neuroma showed quite a different response.

We now refer to a nerve impairment as sensori-neural, indicating that the area involved may be either sensory (that is cochlear or inner ear) or truly neural. Tests of speech discrimination, auditory fatigue, and loudness function help to identify the exact site of the lesion, cochlear or retrocochlear. It is the retrocochlear type of pattern that is found in most cases of acoustic neuroma.

Pure Tone Audiometry

The establishment of the pure tone audiogram is the first step in audiologic evaluation. The patient with an acoustic neuroma will have a sensori-neural type of hearing impairment, usually limited to or worse on the affected side. Furthermore, the configuration or pattern for loss of frequency may be significant. Seventy per cent of 53 surgically confirmed tumors in a recent series had audiograms that showed a loss of high frequency tone perception (Fig. 2).

Speech Audiometry

The second step in auditory evaluation is testing the patient's ability to hear and to understand speech. Understanding of speech (speech discrimination) is usually grossly impaired in retrocochlear lesions.

The tests may be administered by "live voice," record or tape recording through a speech circuit in the audiometer. We prefer tape recording because it reduces distortion and is free from the surface noise present after records have been played a number of times.

The speech reception threshold (SRT) is established by using bisyllabic words (spondee words) such as baseball, cupcake, washboard, etc. The intensity level at which the patient repeats 50 per cent of these words correctly is the SRT and should approximate the threshold for pure tones.

The patient's ability to understand speech is of greater importance. To determine the speech discrimination, monosyllabic words (phonetically balanced or PB words) such as
rip, goose, earth, nudge, etc. are presented to the patient 20 to 40 decibels above the SRT. This increased intensity is to insure that the words are heard loud enough to be understood if possible.

A list of fifty words is presented. The percentage correct is recorded as the PB or discrimination score. Normal patients, and those with a conductive impairment, will have perfect scores (90 to 100 per cent). Those with a sensori-neural hearing impairment will show a varying degree of impaired discrimination.

Cochlear lesions such as Menière’s disease or hereditary or aging changes in the inner ear will show a moderate loss of discrimination. More than half of the words will be understood in most cases.

The patient with an acoustic neuroma will usually show gross discrimination impairment. In the series of confirmed tumors, two thirds had a PB score of 30 per cent or less. Half of those in this group had absolutely no capacity for understanding speech.

**Auditory Fatigue Tests**

A person with normal hearing or one with a conductive impairment is able to hear a continuous tone, presented just above threshold, for a prolonged period of time without developing significant auditory fatigue. In sensori-neural impairments a varying amount of adaptation or auditory fatigue will occur, depending upon the location of the lesion.

Auditory fatigue is minimal, and usually limited to the higher frequencies in cochlear disorders. In cases of acoustic neuroma there may be severe or total tone decay (auditory fatigue).

There are two tests designed to measure this auditory fatigue or adaptation: the modified tone decay test (MTDT), and diagnostic Békésy audiometry.

**Modified Tone Decay Test.** The MTDT is the simpler of the 2 tests. It may be carried out with any standard audiometer in a very brief period of time. The procedure is as follows:

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**Fig. 1.** Audiogram illustrating conductive impairment in the right ear and sensori-neural (nerve) impairment in the left ear. Solid line represents air conduction and dotted line bone conduction.

**Fig. 2.** Audiogram showing high-frequency loss configuration in a verified acoustic neuroma (solid circles). The opposite ear (open circles) is normal.
1. Present a tone 5 decibels above the threshold; start timer.
2. Increase the intensity in 5 decibel steps as the tone becomes inaudible.
3. Determine the amount of tone decay in 60 seconds (the final decibel level minus the initial decibel level).

Individuals with normal hearing and those with conductive hearing impairments will show little or no tone decay (Fig. 3). Cochlear types of sensori-neural impairment (as in Menière's disease) may show up to a 15 decibel tone decay.

Tone decay greater than 15 decibels in 1 minute suggests a retrocochlear or true neural lesion. The tone decay may be moderate (Fig. 4) or complete (Fig. 5). When this amount of auditory fatigue is present it is advisable to proceed with diagnostic Bekesy audiometry.

Békésy Audiometry. Diagnostic Békésy audiometry compares the patient’s responses to interrupted and continuous tones. This comparison demonstrates a variable amount of auditory fatigue in the patient with a sensori-neural hearing impairment. The character of the spread between the interrupted and continuous tone results in 4 distinct patterns. Type I, II, III, and IV (Fig. 6–9). Types III and IV are characteristic of a retrocochlear lesion such as the acoustic neuroma.

Fig. 3. Modified Tone Decay Test: A 2000 cycle tone was heard at an intensity level just 5 decibels above threshold for the entire minute. (Compare with Figures 4 and 5 in which tone decay occurs).

Fig. 4. Modified Tone Decay Test: It was necessary to increase the loudness of the tone by 15 decibels during the 60 second period.

Fig. 5. Modified Tone Decay Test: The tone faded out completely in less than one minute. At maximum output level of the audiometer, the patient was unable to hear the sound.
The Békésy audiometer presents a continuously variable tone at a set rate shifting from 100 cycles to 10,000 cycles. The intensity is continuously changing depending upon the activation of a switch that the patient holds in his hand. He is instructed to push the lever down as soon as he hears the tone and to release it as soon as the tone fades away. The patient thereby controls the intensity of the signal. Whenever he depresses the button the signal becomes softer until he is unaware of the tone. He then releases the button whereupon the signal becomes louder. When he again hears the tone he depresses the button.

The pulsed tone is presented through the

Fig. 6. Békésy tracing, Type I: Continuous and interrupted tone intertwine. Found in normal hearing individuals and those with a conductive hearing impairment.

Fig. 7. Békésy tracing, Type II: Note separation in the mid-frequency range, when the continuous tone drops 5 to 15 decibels below the interrupted tone. Found in cochlear or inner ear disorders.
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Fig. 8. Békésy tracing, Type III: Note early separation and total decay of the continuous tone. Found in retrocochlear disorders such as acoustic neuroma.

entire frequency range; the procedure is then repeated with a continuous tone. It is the relationship between these 2 tracings that is significant.

Patterns of Békésy Tracings. The Type I tracing intertwines the continuous tone and the pulsed tone through the entire frequency range (Fig. 6). This tracing is expected in the patient with normal hearing, in those with a conductive impairment, and in an occasional individual with a sensori-neural impairment.

The Type II tracing (Fig. 7) is characteristic of cochlear disorders. There is intertwining of the pulsed and continuous tone in the low frequencies. In the mid-frequency range a separation occurs when the continu-

Fig. 9. Békésy tracing, Type IV: Note early separation, the continuous tone dropping 20 to 30 decibels below the interrupted tone. Found in retrocochlear disorders.
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The Type IV pattern

The Type III

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The Type III tracing (Fig. 8) is character-

The Type IV pattern (Fig. 9) is also found

continuous tone falls abruptly away from

The Type IV pattern, is indicative of a retrocochlear le-

Loudness Function Tests

We have pointed out how patients with

responses to loudness function tests, however,

the MTDT, or as shown by a Type III or IV Békésy

pattern, is indicative of a retrocochlear le-

Summary (auditory fatigue). Abnormal

fatigue may be demonstrated by the

modified tone decay test or by diagnos-

tic Békésy audiometry. Fatigue or adapta-

tion of more than 15 decibels on the MTDT,

Fig. 10. Alternate Binaural Loudness Balance Test
demonstrating complete recruitment of loudness. There

is a 45 decibel difference in threshold at 1000 cycles. The

initial presentation of the tone sounded equally loud at

zero and at 40 decibels. When the sound was increased

only 10 decibels in the impaired ear it sounded as loud

as a 20 decibel tone in the unimpaired ear. At a level of

40 decibels in the good ear it sounded as loud as 50

decibels in the impaired ear. When the tone was pre-

sented at 60 dB it appeared to be equally loud in both

ears. The poorer side "caught up" to the better although

there was more than 40 dB difference to start with.

ous tone drops 5 to 15 decibels below

the pulsed tone. In some instances the break may

occur in lower frequencies. The amplitude of

the continuous tone excursions after separa-

ation is often smaller.

The Type III tracing (Fig. 8) is character-

istically found in retrocochlear disorders.

The continuous tone falls abruptly away

from the interrupted tone and may not be

heard at the maximum output of the audi-

ometry after a very short period of time.

There is total decay or fatigue.

The Type IV pattern (Fig. 9) is also found

in retrocochlear disease. The continuous tone

drops 20 decibels or more below the pulsed

tone. This tracing may at times be confused

with the Type II tracing (Fig. 7). There are

certain distinct differences, however: 1. The

spread between the pulsed and continuous
tone is 20 decibels or more; 2. The break or

spread frequently occurs in the low frequen-
cies; 3. The amplitude of the continuous tone

excursions is not usually decreased as in the

Type II pattern.

Test procedure and interpretation. The test

is accomplished by presenting a tone of the

Fig. 11. Alternate Binaural Balance Test demon-

strating partial recruitment of loudness. The two ears

have 45 decibel difference in loudness balance at thresh-

hold but only 15 decibel difference at higher intensity

levels. The impaired ear "caught up" partially but not

completely with the good ear.
same frequency alternately to the 2 ears. The patient is asked to compare the loudness of the sound in the normal ear with the loudness of the sound in the impaired ear. The intensity on the normal ear is adjusted to balance it with equal loudness in the impaired ear. The signal is first presented close to threshold and then in discrete increments above threshold.

A varying degree of recruitment is found in cochlear types of sensory neural hearing impairment (Figs. 10 and 11). This represents an abnormal increase in the increment of loudness in the diseased ear. The patient with this type of response will often complain that loud noises hurt or bother the ear. Retrocochlear types of sensory neural hearing impairment do not usually show recruitment (Fig. 12); the ear behaves as a normal one would so far as loudness function is concerned.

Short Increment Sensitivity Index Test. The SISI test measures the patient's ability to detect small increments of loudness. Cochlear lesions result in an abnormal sensitivity to sound and the test score will be high. In retrocochlear lesions the patient is unable to detect small increments of loudness and the test score will be low. The procedure is as follows:

1. A steady tone 20 decibels above threshold is presented.
2. Every 5 seconds a one decibel increase in intensity is introduced for 0.2 seconds.
3. The patient signals when and if he hears the increase in intensity.

![Image](image_url)

Fig. 12. Alternate Binaural Balance Test demonstrating no recruitment of loudness. The 40 decibel difference at threshold remains the same at each subsequent presentation of the tone in the two ears.

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### TABLE 1

<table>
<thead>
<tr>
<th>Auditory Test</th>
<th>Percentage of Cases</th>
</tr>
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<tbody>
<tr>
<td>High frequency loss pattern</td>
<td>70</td>
</tr>
<tr>
<td>Poor speech discrimination</td>
<td>80</td>
</tr>
<tr>
<td>Abnormal auditory adaptation (auditory fatigue)</td>
<td>70</td>
</tr>
<tr>
<td>Normal loudness function</td>
<td>70</td>
</tr>
</tbody>
</table>

4. Twenty separate presentations are made and a 5 per cent score is assigned for each positive response.
5. Cochlear disorders yield a high (60–100 per cent) score.

### Consistency of Auditory Test Findings

No single auditory test can be considered decisive in differentiating a retrocochlear from a cochlear lesion. Ideally the full battery of auditory tests should be administered.

Seven out of 10 of our acoustic neuroma cases have demonstrated consistent or typical retrocochlear test findings (Table 1). The other 30 per cent had individual test results that were indicative of a retrocochlear problem. Some revealed poor speech discrimination and marked tone decay but had a high SISI score and recruitment of loudness. Others in the group had good speech discrimination but a low SISI score, no recruitment and some tone decay. It is important that the full battery of auditory tests be administered to give maximum aid in the differential diagnosis.

We may conclude from reported findings in surgically confirmed cases that approximately 70 per cent will produce typical findings in response to various auditory tests. By administering the entire battery of tests, significant information may be obtained to aid in establishing an early diagnosis in cases of acoustic neuroma.

### Auditory Screening Tests

The physician, regardless of his specialty, may not have available all the equipment necessary to carry out the detailed tests required for a thorough auditory evaluation. Are there then some simple screening tests that will allow him to perform a neurological examination of the auditory nerve in his office? What can be done in the patient’s