Steps for Rapid, Thorough Interpretation of the Audiogram

1) **Assess for hearing loss using pure tone audiometry**
   a. Measure severity of hearing loss (see Table 2) and calculate the PTA.
   b. Check for asymmetry.

2) **Determine the type of hearing loss**
   a. Calculate the air-bone gap.
   b. Determine if masking used.

3) **Check if the audiogram fits a classic pattern**
   a. SNHL
   b. Conductive HL
   c. Mixed HL
   d. Presbycusis
   e. Noise-induced hearing loss
   f. Otosclerosis
   g. Meniere’s

4) **Review the speech reception threshold (SRT) or speech detection threshold (SDT)**
   a. Check for consistency between the SRT and PTA.
   b. If young child or disabled: SDT may be only valid hearing test obtainable.

5) **Assess word recognition testing (WRT)**
   a. Conductive hearing loss: Good WRT scores
   b. Cochlear hearing loss: Reduced WRT scores
   c. Retrocochlear hearing loss: Poor WRT scores

6) **Determine Tympanometry type (see Table 4)**

7) **Check static immittance or middle ear volumes (MEV)**
   a. Normal MEVs: 0.3 to 1.75.
   b. Large MEVs: >1.75
      i. Consider PET in place or perforated TM.

8) **Evaluate acoustic reflex testing (see Charts 1-3)**
   a. In a conductive loss with middle ear pathology, the reflex will usually be absent in the pathologic ear due to a diseased middle ear space.

   b. In cochlear hearing loss, reflexes may be normal due to the presence of recruitment.

   c. In the case of Cranial Nerve 8 pathology, the reflex may or may not be present depending on the degree of nerve damage and tumor extension.

   d. Acoustic decay is often abnormal in cerebellopontine angle tumor.
PURE TONE AUDIOMETRY

Pure tone audiometry is used to determine hearing thresholds at 250, 500, 1000, 2000, 4000, and 8000 Hz using variable sound pressure level intensities.

FIGURE 1: Standard audiogram grid.
Air conduction thresholds are the first measurements obtained during pure tone audiometry. With the use of headphones or insert earphones, the audiologist will play multiple sounds at each frequency and determine the lowest sound pressure level (dB) at which ≥50% of the tones are perceived. These thresholds are recorded on an audiogram grid (see Figure 1). A standard audiogram grid has the sound pressure level along the Y axis, with increasing intensity from top to bottom, and frequency along the X axis. Frequency is ordered with low pitched tones on the left and higher pitched tones on the right. The patient’s thresholds are mapped using coded symbols with X representing the left ear, and O representing the right (see Table 1).

**TABLE 1: Legend of symbols used on a standard audiogram.**

<table>
<thead>
<tr>
<th></th>
<th>Right (red)</th>
<th>Left (blue)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmasked</td>
<td>☺</td>
<td>✭</td>
</tr>
<tr>
<td>Masked</td>
<td>☠</td>
<td>☤</td>
</tr>
<tr>
<td><strong>Bone:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmasked</td>
<td>&lt;</td>
<td>&gt;</td>
</tr>
<tr>
<td>Masked</td>
<td>[</td>
<td>]</td>
</tr>
</tbody>
</table>

Graphically, the horizontal line at “0” on the Y axis is denoted as Audiometric Zero, or the calculated average of the lowest sound pressure heard in thousands of non-pathologic ears. Thus, a patient’s threshold hearing ranges are calculated to be relative to the audiometric zero, not to true sound pressure levels.

Note: A patient’s Pure Tone Average can be calculated by taking the average of the speech frequencies at 500, 1000, and 2000 Hz. The PTA is typically similar (within ~10dB) to the speech reception threshold. (see Speech Audiometry section below).
**STEP 1: Assess for hearing loss**

The first step in interpreting an audiogram is to assess for hearing loss using the air conduction thresholds. If a patient’s thresholds fall below 25 dB, then some degree of hearing loss is present. Once you have characterized whether or not there is an impairment, you can begin to describe it. How severe is the loss? Is it symmetric? Severity of hearing loss is described using the standard terminology shown in Table 2. It is important to note that these terms may not always correspond to the subjective effect an individual’s hearing impairment has on communication.

Asymmetry is judged by comparing the right and left ears. While significant asymmetry is easily picked up on an audiogram, there is not a clear consensus in the literature as to what defines asymmetry. At our institution, we consider hearing loss to be asymmetric when there is a 20 dB difference between the right and left ears at two neighboring frequencies. Asymmetry will often trigger an otolaryngology referral. Asymmetric sensorineural hearing loss should prompt the physician to pursue work-up to rule out a vestibular schwannoma.

**TABLE 2: General classification of severity of hearing loss.**

<table>
<thead>
<tr>
<th>Hearing level (dB)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10 to 15</td>
<td>Normal hearing</td>
</tr>
<tr>
<td>16 to 25</td>
<td>Slight hearing loss</td>
</tr>
<tr>
<td>26 to 40</td>
<td>Mild hearing loss</td>
</tr>
<tr>
<td>41 to 55</td>
<td>Moderate hearing loss</td>
</tr>
<tr>
<td>56 to 70</td>
<td>Moderately severe hearing loss</td>
</tr>
<tr>
<td>71 to 90</td>
<td>Severe hearing loss</td>
</tr>
<tr>
<td>91 plus</td>
<td>Profound hearing loss</td>
</tr>
</tbody>
</table>
**STEP 2: Determine the type of hearing loss**

Once a hearing loss has been identified, the next step is to determine whether it is a sensorineural, conductive, or a mixed loss. A **sensorineural loss** implies that the auditory nerve or the cochlea is damaged. Examples of sensorineural loss include presbycusis, noise-induced hearing loss, and vestibular schwannoma. A **conductive loss** occurs when there is pathology in the external or middle ear that blocks sound from reaching the cochlea. Cerumen impaction, otitis media, cholesteatoma, and otosclerosis are examples of conditions that may manifest with a conductive loss. A **mixed hearing loss** occurs when there is both a senorineural and conductive component.

The type of hearing loss is determined by the presence of an air-bone gap. Once the audiologist has determined a patient’s air conduction thresholds, attention is turned to the bone conduction thresholds. Bone conduction thresholds are measured using a bone oscillator apparatus that is placed overlying either mastoid. Thresholds are measured as the lowest level (dB) at which 50% of the pure tones introduced via the oscillator are perceived by the patient for frequencies between 250 and 4000 Hz. The audiologist makes appropriate markings on the audiogram grid, represented by < for Right, > for Left – as depicted in Table 1.

Note: Bone conduction testing is not specific to the side on which the oscillator is placed. For example, a right-sided oscillator is transmitting pure tones to both the right and left inner ear organs.

The air-bone gap is calculated by subtracting the bone conduction thresholds from the air conduction thresholds. For example, if a patient’s bone conduction threshold at 2000Hz is 10dB and the air conduction threshold is 50dB, the air-bone gap at 2000Hz is reported as 40dB. Each frequency may have a different air-bone gap.

Masking is often employed when there is significant asymmetry between the two ears. It is used to prevent the better hearing ear from creating a false threshold that underestimates the degree of loss in the worse hearing ear. Masking can be applied to bone conduction and air conduction thresholds alike. To perform masking, the audiologist applies headphones or inserts that play narrow band noise centered at the test frequency in the contra-lateral or non-tested ear. This noise is typically 40dB or greater above the pure tone average. This effectively masks the non-tested ear and allows the audiologist to measure the true threshold of the poorer hearing ear.

Note: **Masking dilemma** can occur when there is a moderate to severe conductive hearing loss in both ears. It occurs when the intensity of sound needed to mask the non-test ear is so loud that it crosses over to the tested ear.

Of note, the **Stenger test** should be done in all patients with a unilateral hearing loss and a suspicious history (attention-seeking behavior, direct/indirect financial gain). This test uses the
principle that when two pure tones identical in every way but intensity are introduced simultaneously to both ears, only the sound in the louder ear will be heard. For example, a sound is played 10dB above the voluntary threshold in the supposedly better-hearing ear, and at the same time, a sound is played 10 dB lower in the poorer ear. The patient should acknowledge the signal in the better hearing ear. As the sound is increased in the poorer ear, a patient with a genuine hearing loss will continue to respond to the sound in the better hearing ear. A patient feigning impairment will stop responding to the sound in the good ear once the level in the worse ear is louder relative to the good ear. This lack of an admission is what is referred to as a positive Stenger’s test.
**Step 3: Check if the audiogram fits a classic pattern**

Mild SNHL – bilateral.

Moderate SNHL -bilateral.
Mild CHL – bilateral.
Moderate-to-profound Mixed hearing loss – bilateral.

Presbycusis. Down-sloping SNHL associated with aging.

* An example presbycusis (sloping high-frequency hearing loss) synonymous with the ageing process.
Noise-induced Hearing Loss. Notch-shaped high-frequency sensorineural loss, worst at 4000 Hz.

Bilateral conductive hearing loss. Otosclerosis with Carhart notch at 2000 Hz.

Left Meniere’s disease. Up-sloping SNHL.
SPEECH AUDIOMETRY

Speech audiometry is the part of the audiologic assessment that uses uttered speech, as opposed to pure tones, to assess hearing. This testing provides a way to quantify one’s ability to understand spoken words. There are two main types of speech testing: 1) speech reception threshold (SRT) or speech detection threshold (SDT) and 2) word recognition testing (WRT).

**STEP 4: Review the speech reception threshold (SRT) or speech detection threshold (SDT)**

An important part of speech audiometry is the speech reception threshold (SRT). The SRT is the lowest level at which a listener can repeat bisyllabic words correctly 50% of the time. These bisyllabic words are called spondee words, meaning each syllable has the same weight. Examples include “baseball” and “hotdog.” The significance of the SRT is that it should correspond with the PTA and thus serves as a check for consistency.
**Note:** The better hearing SRT should be consistent with the **sound field** – a threshold that is obtained in a manner similar to the PTA, where, instead of headphones, sound is delivered through loudspeakers on either side of the patient.

Similar to the SRT is the **speech detection threshold (SDT)**. It is the level at which a listener can identify the presence of speech 50% of the time. The SDT is used less often than the SRT, and it is used mostly in the evaluation of select patients, such as profoundly deaf, developmentally delayed, or very young people.

The **most comfortable listening level (MCL)** is typically about 40 dB above the SRT, and it represents the supratheshold level at which a person hears speech. In contrast, the **uncomfortable loudness level (UCL)** is the level above which sound would be painful. Both the MCL and UCL are useful when programming hearing aids in patients with sensorineural loss.
**STEP 5: Assess word recognition testing**

The last part of speech audiometry is word recognition testing (WRT) or speech discrimination testing. For this exam, a list of monosyllabic words is presented to the patient near the MCL and the patient is asked to repeat them. Typically, a pre-fabricated list of at least 25 words that include all the sounds of the English language are presented and the patient is given a percentage score that reflects the number of words that s/he repeated correctly. Word recognition testing is important because it can assist in the diagnosis of the type of hearing loss. For example, in a conductive loss, speech discrimination is usually excellent, whereas in a cochlear loss, it is usually reduced. In the case of a retrocochlear loss, word recognition is very bad, even in the setting of normal PTA’s. This finding makes sense in the context of cortical lesions, the extreme example being a Broca’s aphasia. Of note, some audiologists use the categories outlined in Table 3 to describe the word recognition score.

**Note:** Rollover is a term associated with retrocochlear impairment. After the level at which maximum word recognition has been obtained (called PB max), rollover is the phenomenon whereby further increases in intensity cause decreased word recognition.

<table>
<thead>
<tr>
<th>Score (%)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>90-100</td>
<td>Excellent</td>
</tr>
<tr>
<td>75-89</td>
<td>Good</td>
</tr>
<tr>
<td>60-74</td>
<td>Fair</td>
</tr>
<tr>
<td>50-59</td>
<td>Poor</td>
</tr>
<tr>
<td>&lt; 50</td>
<td>Very poor</td>
</tr>
</tbody>
</table>
IMMITANCE

Imittance is a measure of energy, either the opposition to the flow of energy (i.e., impedance), or the flow of energy through a system (i.e., admittance). To measure immittance, the external ear canal is sealed with an air-tight probe that is connected to a device that delivers a tone. The reflected acoustic energy is measured from the intensity of the tone in the ear canal. A TM with low impedance (and high admittance) more readily transfers the acoustic energy from the probe tone, whereas a TM with high impedance (and low admittance) is more resistant to that energy flow. There are three arms to immittance testing: tympanometry, static immittance, and the acoustic reflex.

**STEP 6: Determine Tympanometry Type**

Tympanometry

Tympanometry is a measure of immittance at various air pressures in the external ear. The X axis of a tympanogram is air pressure. The Y axis reflects immittance, but this is easiest to think about in terms of TM mobility or compliance. A normal middle ear is most compliant at ambient pressure, thus the peak in a normal tympanogram at 0 mmH2O.

Tympanograms are classically defined as type A, B, or C. A normal, or type A tympanogram, has a central peak at ambient pressure. A type B tympanogram has a flat line with no peak in compliance. This is most commonly associated with otitis media with effusion, since the fluid in the middle ear space dampens TM mobility. It can also be associated with TM perforation or a mass in the middle ear. On a type C tympanogram, the peak in compliance is shifted leftward towards the negative pressures. Type C tympanograms are common in patients with a retracted TM and Eustachian tube dysfunction.

Note: There are two variations in the type A tympanogram: AS and AD. AS stands for shallow, so peak compliance is reduced, as is commonly seen in ossicular chain (OC) fixation. AD stands for deep, and peak compliance is increased, indicating ossicular chain hypermobility or, less frequently, a healing TM perforation.

![Tympanometry Diagram](image)
<table>
<thead>
<tr>
<th>Tympanograms Type</th>
<th>Middle Ear Pathology</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>OME, perforation, mass</td>
</tr>
<tr>
<td>B</td>
<td>ETD</td>
</tr>
<tr>
<td>C</td>
<td>OC fixation</td>
</tr>
<tr>
<td>D</td>
<td>OC hypermobility, healing TM perforation</td>
</tr>
</tbody>
</table>

Table 4: Tympanograms type A-C, AS, and AD and their corresponding middle ear pathologies.

**STEP 7: Check static immittance or middle ear volumes (MEV)**

*Static Immittance*
On an audiogram, **static immittance** is expressed as a volume (usually in cubic centimeters). This refers to the volume of air that would have the immittance properties that were measured. On most audiograms, static immittance is recorded as the middle ear volume. Normal values for middle ear volume range from 0.3 to 1.75.

**Note:** An abnormally large volume may represent a perforation in the TM or the presence of a PE tube.

On some audiograms, two measurements are used to calculate middle ear volume. These are usually reported as C2 and C1. C2 is the volume measured during the condition of maximum TM mobility, in other words when the pressure in the EAC equals middle ear pressure (at 0 mmH2O in a normal ear). When the pressures are the same, there is coupling of the EAC and the middle ear, so C2 represents the summation of the volumes of these two compartments. You can think of it like the top of the tympanometry curve. C1 is the volume measured during minimal TM mobility. When the pressure in the EAC is different from middle ear pressure, the TM is either bulging or retracted, and there is decoupling of the EAC and middle ear. After a tone is delivered, the probe measures more sound reflection off the TM since admittance through the middle ear is reduced. The measured value corresponds to the volume of the EAC. You can think of C1 like the bottom of the tympanometry curve.

Having defined C2 and C1, it makes sense that the difference between these two measurements is equivalent to the middle ear volume. This value is significant because it reflects the integrity of the TM and, combined with the tympanogram, may further aid in diagnoses.

**STEP 8: Evaluate acoustic reflexes**

*Acoustic reflex*
The *acoustic reflex* refers to the contraction of the stapedius muscle in response to loud sounds. With sufficient sound, the stapedius muscle moves the stapes away from the oval window, stiffening the ossicular chain and flexing the tympanic membrane. This is recorded as a change in immittance. The measurement of the *acoustic reflex threshold* refers to the lowest intensity tone that elicits contraction. In a normal hearing ear, the acoustic reflex usually occurs above 80dB. It is useful clinically because it can help define the location responsible for hearing loss, specifically, whether it stems from the middle ear, the cochlea, eighth cranial nerve, or the facial nerve.

**Note**: Acoustic reflex thresholds are reported with respect to the ear that receives the probe tone and are referred to as ipsilateral or contralateral to the ear stimulated. A “right contralateral reflex,” for example, is when the signal goes to the right ear and the measurement is taken from the left ear.

The following flow chart summarizes the expected findings according to the location of the pathology responsible for the hearing loss.

- **Bilateral loss**
- **Unilateral loss (R Ear)**
  - No reflexes

  **Middle ear pathology**
  - R ear stimulated
  - L ear stimulated
  - No reflexes
  - Ipsilateral reflex present
  - Contralateral reflex absent

**Chart 1.** Showing the expected outcomes of acoustic stapedial reflex with a conductive loss. For demonstration purposes, when there is a unilateral loss we will assume that the right ear is affected. There are no ipsilateral or contralateral reflexes when the right ear is stimulated due to insufficient intensity of sound in the poorer hearing ear. There is no contralateral reflex when the left ear is stimulated due to the presumed right middle ear pathology.

- **Bilateral loss**
- **Unilateral loss (R ear)**

  **Cochlear pathology**
  - R ear stimulated
  - L ear stimulated
  - Both reflexes present
  - Depends on the degree of hearing loss
  - Depends on the degree of hearing loss
Chart 2. Showing the expected outcomes of the acoustic stapedial reflex in unilateral, right-sided sensorineural hearing loss of cochlear origin.

**Note:** A person with cochlear hearing loss will often have a normal acoustic reflex. This is because despite a significant sensorineural hearing loss, sounds starting at 80 to 100 dB are still perceived as loud. This phenomenon is called *recruitment*.

Unilateral loss (R ear)

CN 8 pathology

- R ear stimulated
- L ear stimulated
- Both reflexes present
- Absent/elevated/present with decay

Chart 3. Showing the expected outcomes of the acoustic stapedial reflex in right-sided nerve 8 pathology. When the right side is stimulated, both ipsilateral and contralateral reflexes will either be absent, present but elevated, or present with acoustic decay.

**Note:** In a retrocochlear pathology, an acoustic reflex may or may not be present. There are two reasons that the reflex may be absent. First, there is no recruitment in retrocochlear hearing loss, since there is decreased sensitivity for all sounds due to nerve damage. Second, the pathology, ie. tumor, may actually injure one of the nerves involved with the reflex. For example, cranial nerve 7 travels through the internal acoustic meatus, and a large enough tumor could damage the nerve directly.

*Acoustic decay*
Acoustic decay reflects the function of the afferent and efferent cranial nerves involved in the stapedial reflex arc, namely 8 and 7, respectively. Acoustic reflex decay is abnormal if after sound is presented 10 dB above the acoustic reflex threshold, the response intensity decreases by more than half in five seconds. Often in vestibular schwannoma, there is abnormal acoustic decay. It is worth noting that acoustic decay is not pathognomonic for CN 8 lesions, as there is a high false-positive rate in Meniere’s patients (as many as 27%). This technique is also a sensitive measure of seventh nerve function. In Bell’s palsy, the reflex decay may initially be abnormal, but it is often one of the earlier markers of recovery.

**GLOSSARY**

**Acoustic reflex**
- The contraction of the stapedius muscle in response to loud sounds.

**Acoustic reflex threshold**
- The least intense sound that elicits contraction, normally between 80 – 100 dB.

**Air-Bone Gap**
- The calculation obtained by subtracting the air conduction thresholds from the bone conduction thresholds at each individual frequency.

**Air conduction threshold**
- First step to pure tone audiometry testing. A determination of the patient’s lowest level (dB) of hearing at which ≥50% of perception occurs.

**Audiometric zero**
- The horizontal line at “0” on the audiogram grid. This value is a calculated relative threshold obtained by averaging the lowest sound pressure level heard in thousands of non-pathologic ears.

**Bone conduction threshold**
- Second step to pure tone audiometry testing. Bone oscillator apparatus placed overlying one mastoid at a time and threshold is calculated as the lowest sound pressure level (dB) at which 50% of the pure tones introduced via the oscillator are perceived.

**Conductive hearing loss**
- Measured by the presence of an air bone gap. Signals the presence of pathology in the external or middle ear that is obstructing normal sound transmission.

**Immitance**
- A measure of energy through a system.

**Masking**
- Utilized when performing bone conduction testing to help lateralize the bone conduction findings. In-the-ear inserts or headphones are used to play narrow band noise in the contralateral ear at a level >40dB then the pure tone emission from the oscillator.

**Most comfortable listening level**
The supratheshold level at which a person most comfortably hears speech.

**Pure tone audiometry**

One of three portions of any standard audiogram. This is generally performed to determine levels of air and bone conduction at 250, 500, 1000, 2000, 4000, and 8000 Hz at variable sound pressure level intensities.

**Pure tone average**

A calculated average using thresholds garnered at the frequencies at 500, 1000, 2000 Hz. This average should be very close to the speech reception and detection thresholds (within 5 dB).

**Recruitment**

The phenomenon in cochlear hearing loss whereby intensities that would be perceived as loud in a normal hearing person are still perceived as loud despite a sensorineural hearing loss.

**Rollover**

A phenomenon in retrocochlear impairment whereby further increases in intensity cause decreased speech recognition scores.

**Sensorineural hearing loss**

Evident on pure tone testing. Denotes pathology either of the cochlea or auditory nerve.

**Sound Field**

A threshold that reflects the patient’s lowest sound pressure level (dB) of hearing at which ≥50% perception occurs when sound is delivered through loudspeakers on either side of the patient.

**Sound pressure**

The ambient air pressure change measured when a sound is emitted. This is measured in pascals.

**Sound pressure levels**

These represent the Y-axis on the audiogram grid. They are calculated on a logarithmic scale using the sound pressure (pascals) relative to the audiometric zero. A decibel (dB) is the unit of measurement for this calculation.

**Speech detection threshold**

The level at which a listener can identify the presence of speech 50% of the time.

**Speech discrimination testing**

A type of test whereby a list of monosyllabic words is presented to the patient near the MCL and the patient is asked to repeat them.

**Speech reception threshold**

The lowest level at which a listener can repeat bisyllabic words correctly 50% of the time.
Spondee words
Bisyllabic words where each syllable has the same weight.

Static immitance
A representation of middle ear volume, usually expressed in cubic centimeters.

Stenger Test:
A test used for patients in which you suspect malingering or pseudohypoacusis.

Tympanometry
The measurement of tympanic membrane mobility at various air pressures in the external ear.

Uncomfortable loudness level
The lowest level at which sound is painful.

Word recognition testing
Same as speech discrimination testing.

References (images used/modified from):