Dr. Jason Barnes:

Hey there. Welcome to another episode of ENT in a Nutshell. My name is Jason Barnes. Today we're joined by audiologist Jill Gruenwald and Dr. Matt Carlson, neurotologist. We will be discussing the audiogram. Jill, Dr. Carlson, thanks so much for being here.

Dr. Matthew Carlson:

Thank you for having us.

Dr. Jill Gruenwald:

Thank you.

Dr. Jason Barnes:

So just to hop in, I want to say that today we'll be talking mainly about the adult audiogram. There are other forms of "hearing" tests, which include the OAEs, ABRs, and there's more specific cochlear implant testing, which we won't be talking about quite as much today. But I was hoping we could just walk step-wise through what an audiogram looks like for an adult patient. So, Jill, when you see these folks who come for a "hearing" test, can you tell us what that looks like when you perform an audiogram?

Dr. Jill Gruenwald:

I spend most of my day in a windowless sound booth. So the patient will come back into a room that has been sound-treated to be very quiet. We adhere to standards of how loud the ambient noise can be in the room. So lots of sound treatment, soundproofing in those booths.

We take a case history. We perform otoscopy. We will determine what types of headphones to use. We have options to use headphones that sit over the patient's ears and we have options to use foam insert earphones that go into the ear canals. Then we play a series of tones, trying to pick up on the softest sounds those patients can hear.

Dr. Jason Barnes:

How do you decide whether or not you do over-the-ear headphones versus the ear buds?

Dr. Jill Gruenwald:

That's a great question. Sometimes it will have to do with the patient's ear. If we think that we run the risk of what's called a collapsing canal, we will choose an insert earphone. A collapsing canal is when the weight of the headphone pushes back on the ear canal and gives us a little hearing loss. That's because the ear canal is closing, not because of a real change in threshold.

Insert earphones have the advantage of a greater interaural attenuation. I think we're going to talk masking later, and that'll come into play when it talks about if we have to mask. Although some patients find insert earphones uncomfortable. They do have to be rolled up and go quite deep into the ear canal. So for pediatric patients or patients with comfort issues, we may stick with the supra-aural, over-the-ear earphones.

Dr. Jason Barnes:

Before we get much further into how the audiogram was performed and what it looks like on paper, can you remind us a little bit about what sound is? What is a decibel? What does zero dB mean and what does this look like in terms of day-to-day function?

Dr. Jill Gruenwald:

A decibel is a unit of sound measurement. It's based on the power of 10. There are different decibel scales. There are decibel scales and sound pressure level or dB SPL. This is measured relative to 20 micropascals, the quietest sound pressure level that normally hearing people hear. It's an absolute value. So when you're talking about decibels in the community as measured with a sound level meter, you're talking about dB SPL.

What's different is on the audiogram. The human ear hears at different dB SPL by pitch. So for the dB HL scale, which you see on the audiogram, normal hearing is normalized to zero. So a straight zero on the audiogram dB HL is normal hearing. Then we have ranges around that.

Essentially, a decibel of zero is the reference range of silence and 10 dB is 10 times that loudness or intensity and 20 dB is 100 times that loudness or intensity. It's on a logarithmic scale.

Dr. Jason Barnes:

Can you give us an idea of what normal conversation is, at what decibel does that occur? What are some examples of extremely loud decibels?

Dr. Jill Gruenwald:

Normal conversation would be around 60 decibels. A jet engine is going to be around 120 decibels. A whisper might be around 30 decibels.

Dr. Jason Barnes:

So now that we've laid the foundation for that, let's start talking about the audiogram, which, at face value, we're talking about a box with a bunch of dots and lines on it. Could you briefly walk us through what this box is? What's the X axis, what's the Y axis, and what do these dots represent?

Dr. Jill Gruenwald:

The X axis going horizontally is going to be your frequency or pitch. It is ordered from low pitches on the left to higher pitches on the right. The Y axis vertically is going to be the hearing threshold measured in decibels HL. So zero decibels will be near the top and loud sounds, 120, 130 decibels, will be near the bottom.

At every pitch, we measure the softest sound the person can hear. We call that their threshold. That's the lowest intensity at which the patient responds 50% of the time, and we plot that on the audiogram using X's for the left ear and O's for the right ear.

Dr. Jason Barnes:

Can you tell us what's considered low frequency, mid frequency, and high frequency on the audiogram?

Dr. Jill Gruenwald:

On the audiogram, which is largely created to measure speech, we consider low frequency is 250 and 500 hertz, mid frequency is 1,000 to 2,000 hertz, and high frequency is 4,000 to 8,000 hertz. If we have any music aficionados listening, we know that for music, that's very different.

Dr. Jason Barnes:

What's the range of frequencies for human speech?

Dr. Jill Gruenwald:

When we're born, humans can hear from 20 hertz to 20,000 hertz. The audiogram is really focused on that speech range 250 to 8,000 hertz, although there are some extended high frequencies that can be tested for special purposes.

Dr. Jason Barnes:

When you're performing an audiogram, how do you decide which frequencies to obtain? Is there a standard set of frequencies that you obtain? What are some rules around when you do or do not obtain additional frequencies?

Dr. Jill Gruenwald:

The standard audiogram will include thresholds measured at 250, 500, 1,000, 2,000, 4,000, and 8,000 hertz standard. If we see a difference between those octaves of greater than 20 decibels, we will test what is called the interoctave. So between 500 and 1,000, that's 750 hertz. Between 1,000 and 2,000, it's 1500 hertz. Between 2,000 and 4,000, 3,000. Between 4,000 and 8,000, 6,000. 3,000 and 6,000 hertz in particular are very sensitive to noise exposure. So a lot of clinics have begun standardly testing 3,000 and 6,000 almost every time.

Dr. Jason Barnes:

When you perform an audiogram, there's the air conduction and the bone conduction thresholds. So this starts to measure different types of hearing. Can you give us a description of what air conduction means and what bone conduction means? Then how do you test these different types of hearing?

Dr. Jill Gruenwald:

When we are testing via air conduction, we are using either a supra-aural headphone or an insert earphone to send the sound wave through the entire chain. That sound wave has to go through the ear canal, the tympanic membrane, the ossicles. It has to reach the cochlea and travel up the nerve to be heard by the brain. That is our air conduction pathway.

When we're testing via bone conduction, we are using the bone oscillator or the bone vibrator, a little black box that we put on the mastoid process behind the ear. That is going to use vibration to send that sound wave via the bone to the cochlea, bypassing the outer ear and the middle ear entirely.

Dr. Jason Barnes:

Does that bone oscillator sit on the ear? Is there an apparatus that places that there, or is it being held there?

Dr. Jill Gruenwald:

It is being held by a headband on the mastoid process. It will stimulate hearing on both sides. So you can also put bone oscillators on the forehead in cases where you can't put it on the mastoid or really any part of the skull bone, although there might be corrections you have to use if you have to change the placement from the mastoid.

Dr. Jason Barnes:

I know, maybe it was someone with perfect hearing, their air conduction is going to equal bone conduction most likely, which we'll talk about in a second. So how do you know when to obtain bone conduction? Do you always obtain it, or is there some rule you follow in terms of when you obtain bone conduction?

Dr. Jill Gruenwald:

If you're seeing a new patient that has never been seen before, it is good practice to test bone conduction every single time. Sometimes if we have a known bilateral, symmetric hearing loss, say, from the aging process and the person comes two years later and the air conduction has not changed at all, we'll assume the bone conduction hasn't changed at all either and not test for bone.

Sometimes if somebody has a completely normal hearing audiogram via air conduction and there's no suspicion of something like superior canal dehiscence or any conductive components, bone conduction will be skipped. But in general, it should be there just about every time.

Dr. Jason Barnes:

Next, I wanted to talk about the different types of hearing loss, which we're starting to get into with air conduction and bone conduction. Dr. Carlson, can you briefly describe to us the examples of air conduction, what that means, and bone conduction, what that means? Then maybe what's on your differential diagnosis for the different types of hearing?

Dr. Matthew Carlson:

Yeah, absolutely. That's a great question. Classically, we would describe a conductive hearing loss as any condition that affects the auditory pathway that inhibits the sound waves to reach the cochlea and stimulate the hair cells. So technically it could be starting from, externally, you could have a congenital aural atresia. You could have cerumen impaction. You could have otitis externa, a thickened tympanic membrane, a tympanic membrane perforation, ossicular discontinuity, tympanosclerosis, otosclerosis, anything that's affecting the ossicular chain up until the cochlea. We'd call that conductive hearing loss.

Over recent years, we've developed an understanding that there is a so-called inner ear conductive hearing loss, and there's two or three conditions that can cause that. It's probably because the energy is still dissipated before it actually causes deflections in the hair cells, even though it's involving the inner ear. So examples of that are typically third window conditions, so superior canal dehiscence and large vestibular aqueduct are two examples that we'll commonly talk about that are associated with inner ear conductive hearing loss.

There's also an interesting phenomenon that sometimes we'll perform cochlear implantation with attempted hearing preservation. In the low frequencies, post-operatively, initially they'll have an air-bone gap or conductive hearing loss, but over time that effusion will resolve and they'll still be left with a conductive hearing loss. There is some thought that perhaps the electrode within the scala tympani is pushing on the basilar membrane, and that might actually also cause inner ear conductive hearing loss. A little bit more detailed, but just to point out the fact that most conductive hearing losses relate to disorders affecting anything up to the cochlea, but there are rare exceptions where you can have inner ear conductive hearing loss.

Sensorineural hearing loss most commonly indicates a condition that has an end effect on the sensory hair cells, the mechanosensory hair cells affecting the inner ear. The inner ear hair cells are important for actually sending the electrical signal to the brain, which is perceived as sound. The outer ear hair cells are primarily involved in refining that sound for the inner ear hair cells to transmit that signal.

We're born with about 15,000 inner ear hair cells at birth and a larger number of spiral ganglion cells, which are the bipolar neurons that convey that signal to the brain. Over time, every day we live, every time we hear a little bit of loud noise, any time we have an ototoxic medication, perhaps we have a hereditary disposition or we're aging, all these can result in varying degrees of sensorineural hearing loss.

There are other conditions that can cause sensorineural hearing loss besides conditions affecting the inner ear. So you can have conditions affecting the auditory nerve itself or the cochlear nerve. Examples of that might be a person who's had prior radiation, a person who's had prior posterior fossa surgery, a person born with hypoplasia or aplasia of the cochlear nerve, or even a traumatic avulsion, for example, of the cochlear nerve.

Then even more proximal, you can have conditions of the brain stem, in the supratentorial space that affects auditory perception, including cognitive disorders, which affects the processing of the signal even though you're getting a refined signal.

So when we're talking about the entire pathway, conductive is typically a peripheral process, sensorineural is typically from the cochlea and more proximally. Then you can have a mixed condition. For mixed condition to occur, your bone conduction thresholds have to be worse than normal. So you have to have at least a 25 decibel or worse bone conduction line. Most people will say at least a 10 dB air-bone gap for it to be really considered a true air-bone gap.

Dr. Jason Barnes:

I was going to say we threw around the term air-bone gap, but, Jill, could you tell us functionally what that looks like on the audiogram and what that means?

Dr. Jill Gruenwald:

Yeah. If the bone conduction threshold on the audiogram is better than the air conduction threshold by 10 dB or greater, we will refer to that as an air-bone gap. You're hearing better by bone conduction than air conduction.

Dr. Jason Barnes:

What are your limits in terms of performing air conduction and bone conduction on patients? How high can you go or what are some other limitations that keep you from conducting these measurements?

Dr. Jill Gruenwald:

We do have limitations of the audiometer, how loud our equipment can actually present the signal. We have limitations on what we call the transducer, which for air conduction is the headphones or the insert earphones, how loud they can get. For bone conduction, it is that bone oscillator.

The other limitation we have is that if we get sufficiently loud, if someone has a lot of hearing loss via air or bone, the threshold could become vibrotactile. That means that the patient is actually feeling the signal. They can feel the sound wave rather than hear it, and they will respond. You can see this on your audiogram. Usually there will be a little V next to the symbol for vibrotactile.

Dr. Jason Barnes:

Just functionally, that means for the clinician reading it that they basically don't have hearing in that ear. Is that correct?

Dr. Jill Gruenwald:

Or that it's poorer than what we can represent on the audiogram, because the patient is feeling it. So we can't get it any louder to determine what is hearing and what is feeling.

Dr. Jason Barnes:

Can you describe how we can bring all of this information together to make it one number, otherwise known as a pure-tone average? What are the breakdowns of the different magnitudes of hearing loss that we talk about?

Dr. Jill Gruenwald:

A pure-tone average is the average of the thresholds at 500, 1,000, 2,000, and 3,000 hertz. If you are looking at an audiogram that does not have 3,000 hertz, you can take the average of 2,000 and 4,000 and use that in your pure-tone average.

Then the magnitude of hearing loss ranges from normal hearing sensitivity to profound hearing loss. We consider normal hearing to be thresholds better than 25 decibels. That is to say zero to 25 decibels. Mild hearing loss would be 25 to 40 decibels, moderate hearing loss, 40 to 55 decibels, moderately severe hearing loss, 55 to 70, severe, 70 to 90, and profound hearing loss are thresholds greater than 90 decibels.

Dr. Jason Barnes:

Do you give one diagnosis for a patient that they have moderate hearing loss or they just have profound hearing loss based on a pure-tone average, or do you look at the different variations among frequencies?

Dr. Jill Gruenwald:

That will vary clinician to clinician as well. A lot of providers will look at an audiogram and some will just take the average of where most of the pure tones are, and then they'll report, write that it is one of these categories. Some clinicians will get very specific and say at this frequency, it is normal, at this frequency, it is moderate, at this frequency, it is severe. So a good knowledge of how to read the graph to accompany the written report is really good to have.

Dr. Jason Barnes:

A final question on that point is I believe there's a caveat for kids. How does that change in children in terms of what normal hearing is?

Dr. Jill Gruenwald:

That's true. For adults, we have assumed that they have already developed speech and language and, therefore, we call normal hearing thresholds better than 25 decibels. For children who may not have developed speech and language, there are some very soft speech sounds that can occur between 15 and 25 decibels. Therefore, we call normal hearing between zero and 15. They will sometimes call it slight hearing loss, 15 to 25 decibels.

Dr. Jason Barnes:

As we continue to talk about obtaining the audiogram, the topic of masking comes up. I think it's pretty confusing for ENT residents, certainly. Can you unpack what the role of masking is in the setting of obtaining an audiogram? When does this become applicable and what does it mean clinically in terms of how we interpret the audiogram?

Dr. Jill Gruenwald:

This is one of the most complicated concepts for audiologists to learn as well. If you have asymmetric sensorineural hearing loss, you will likely not see any masking on your audiogram. Masking comes into play when we are suspicious that the tone we are presenting to one ear could be crossing over to the other ear. Sometimes we call it the test ear and the non-test ear.

So remember that every type of headphone we use has a different level at which the sounds can crossover. When we are using supra-aural headphones and testing by air conduction, a difference of 40 decibels could possibly crossover to the non-test ear. For insert earphones, it's more like 55 to 60 decibels. When we're using the bone oscillator, we assume that the minimum interaural attenuation is zero. It could be crossing over at any time.

In order to know which ear is giving us that response, we will introduce something called masking. Masking is when we deliver noise to the non-test ear to be sure that it cannot be responding to what we are presenting to the test ear. That gives us confidence that we are testing each ear individually.

Dr. Jason Barnes:

So can you give us an example of how you might use this masking to mask the non-test ear?

Dr. Jill Gruenwald:

Yeah. So if I am a patient who has a normal hearing response in one ear and I'm using supra-aural headphones and they respond at, let's say, 50 decibels in the test ear, that is greater than the interaural attenuation of 40. I cannot be confident without masking that that 50 decibels is accurate and not crossing over to the better-hearing ear.

So the audiologist will present narrowband noise at that pitch. In the non-test ear, the patient hears a soft "shhh" sound. We present the tone again. If it stays put, then we know that's an accurate tone. If we have to increase the volume, we know that was a tone achieved by a crossover.

Dr. Jason Barnes:

When we're talking about masking, there's another term we use called the masking dilemma. Can you explain that in a bit more detail?

Dr. Jill Gruenwald:

The masking dilemma is common when we have two ears with a maximum or near-maximum air-bone gaps or conductive hearing loss. When I'm trying to isolate the ears, I cannot present enough noise to the non-test ear without it crossing over to the test ear. Therefore, I cannot mask individually and do not know where the sound is coming from.

Dr. Jason Barnes:

The dilemma is that you can't deliver the signal to the contralateral ear because of the conductive hearing loss. So as we continue to talk about the audiogram, we've talked about the X's and the O's representing the left and the right ear and how we obtain the spots on the graph. We've talked about air conduction and bone conduction representing conductive and sensorineural hearing. Could you just describe when we see a bracket on the audiogram, what does that mean? What does it mean if there's a down-pointing arrow on that bracket?

Dr. Jill Gruenwald:

The brackets are thresholds for bone conduction. You will see two types of brackets. There's a bracket that looks like a greater than or less than sign. That is an unmasked bone threshold. There is also a separate symbol for a masked bone conduction symbol. So it would be good to look at your key and be familiar with the different audiogram symbols. If you see a downward-pointing arrow on any of the symbols, that means no response was obtained at the limits of the equipment. It's assumed that the hearing threshold is poorer than that symbol.

Dr. Jason Barnes:

Is there a pretty classic threshold at which you can decide someone's hearing loss is? If there is the downward-pointing arrow, for example, does that mean it's worse than 100 or worse than 125 dB, or is there not control in that regard?

Dr. Jill Gruenwald:

Yeah. Because our equipment is at the limits, it could be five decibels worse than where that downward-pointing arrow is. It could be 50 decibels worse than where that downward-pointing arrow is, and there's no way for us to know based on our equipment.

Dr. Jason Barnes:

So as we wrap up what the graph looks like on the audiogram, there are some classic audiogram patterns that are worth talking about and thinking about or having on the front of your mind when you're seeing these audiograms. Dr. Carlson, do you mind just running us through some of these more classic audiogram patterns?

Dr. Matthew Carlson:

Yeah, absolutely. I think we can break them down into sensorineural hearing loss patterns, as well as conductive or mixed hearing loss patterns, and the different diseases that classically present that way. It's probably important to emphasize that these are just patterns and there is extreme variability in the way they may present clinically. As with everything in medicine, you have to take the full context of the patient when you're interpreting the audiogram. But having said that, there are some characteristic features or patterns that we often see.

So, for example, a noise-induced hearing loss, whether from a single loud exposure, but more commonly from sustained loud noise exposure from somebody who's a farmer or exposed to heavy machinery over time can have a 4K notch. It's commonly bilateral, but in many cases it could be unilateral. A unilateral noise notch around 4K is frequently seen in people who have an asymmetrical exposure to noise.

So, recreationally, that might be somebody who fires a long gun, a rifle or something like that, where there's a degree of head shadow effect protecting one of the ears. Whereas, for example, a handgun is typically a little bit more symmetrical. Or you could have the farmer that's always looking over his left shoulder when they're watching their combine or they're driving a tractor is another example where you may have asymmetrical noise notch.

Presbycusis typically results in a gradual high-frequency, downsloping, symmetrical sensorineural hearing loss affecting both ears. A mid-frequency loss, typically called a cookie bite, is indicative of a hereditary hearing loss. It's common that a young adult or a mid-age adult will develop this if they have a family history of hearing loss. A low frequency, particularly if it's fluctuating, asymmetrical hearing loss is commonly indicative of Meniere's disease.

I would say that these are the most common patterns we see with sensorineural hearing loss, or at least those are commonly talked about. We can talk about conductive hearing loss.

So starting at a low-frequency air-bone gap, particularly when there's an added Carhart notch ... A Carhart notch is an artificial depression bone conduction threshold centered on 2,000 hertz ... This is most indicative of otosclerosis, but there are other diseases that can often result in a Carhart notch. It's nonspecific. You can also have low-frequency conductive hearing loss involving other diseases.

You can also have that so-called inner ear conductive hearing loss that we talked about earlier. Most commonly, you'll see ... In superior semicircular canal dehiscence, in the affected ear, you'll see superconducting bone thresholds. So the bone conduction thresholds will be at -10. The hearing is very acute or very good in the low frequencies on bone lines. Then your pure-tone thresholds will be slightly worse. So it creates this air-bone gap.

But the contributions to the air-bone gap are different for superior canal dehiscence than for otosclerosis, at least it's believed so. That is because the air-bone gap is created by a better bone conduction threshold and a slightly worse air conduction, so that spreads the gap, versus otosclerosis, it's typically primarily the conductive component that drops your pure-tone thresholds.

Dr. Jason Barnes:

Jill, can you give us a description of what might be described as asymmetric hearing loss on an audiogram?

Dr. Jill Gruenwald:

This is hotly debated in most audiology clinics and with most physicians, I believe. But, generally, if you see a 15-decibel gap at two contiguous frequencies or 10 decibels at three contiguous frequencies, it would be reasonable to call that asymmetric. We will also look at the word recognition scores. I think we're going to talk about speech testing in a little bit. Also hotly contested what is considered an asymmetry, although many clinics will adopt a 15% difference.

Dr. Jason Barnes:

So we've talked about obtaining the pure tones, listening to the tones to each ear. I next want to move on to speech recognition. Jill, can you give us an idea of how you test that and what that looks like in the sound booth?

Dr. Jill Gruenwald:

We usually do two types of speech testing in a normal adult battery. The first is called the SRT or the speech recognition threshold. These are two-syllable words that have an equal amount of stress on each syllable. Some common ones might be airplane, cowboy, baseball. We will lower the volume of these words and call the threshold where the patient gets 50% of the words correct.

The SRT is largely a cross-check for the pure-tone thresholds. They should match up with. The softest sounds by tones and the softer sounds by speech for that test should be relatively similar. Sometimes this helps us understand if a person is exaggerating or malingering on a hearing test.

The other type of speech test we do is the word recognition score. These are going to be monosyllabic words, usually a list of phonemically balanced words, which means the list will represent all the phonemes of the language ship-wreck. We will score the words correct.

Most clinicians are looking for the maximum performance the patient can have. Generally, we get the maximum performance through adequate audibility. We will choose a volume that is 30 to 40 decibels above the pure-tone average. Although if you have somebody with a quite severe flat hearing loss, that might be too loud. If you have somebody with a very steeply sloping hearing loss, you might need more audibility in the high frequencies to get a maximum performance.

The only guaranteed way to get a patient's maximum performance is to present word lists at more than one volume. Typically, we don't have a lot of time to do that clinically, so the clinician is selecting one or two volumes presenting a word list and recording the percentage correct.

Dr. Jason Barnes:

So between different patients, you're not necessarily doing the word recognition score at the same volume.

Dr. Jill Gruenwald:

Not necessarily. Although it depends what you are looking for. If you're looking for changes in word understanding ability and the pure tones have not changed, it may be beneficial to present the words at the same volume to see if there's big changes in word recognition score. If the patient's hearing loss is progressing, then presenting at the same volume may just mean less audibility. A lower percentage score simply means they couldn't hear as much. So, generally, if the patient has more hearing loss, we present at a higher volume.

Dr. Jason Barnes:

Could you speak a little bit to the differences in how maybe an outside provider might obtain word recognition score and how those differences might actually matter?

Dr. Jill Gruenwald:

It'll be important to look at the level at which the speech was presented. That can vary center-to-center as it's the provider's discretion a lot of times how loud they are going to present the speech signal. If there's not sufficient audibility, we think we'll get a lower score.

The other thing that can happen across clinics is you can present recorded stimuli, meaning that you are using a computer or a tape or a compact disc to present word lists that have been specially calibrated and recorded by one speaker, or you can use monitored live voice. Monitored live voice is when the clinician reads the list of words and tries to monitor or calibrate their own volume. It's widely known that monitored live voice results in greater variability in scores and generally higher percentage scores than if you use recorded stimuli.

Dr. Jason Barnes:

Is there a generally accepted variability among word recognition score even by the same patient and the same audiologist?

Dr. Jill Gruenwald:

There will be. A lot of that will hinge on the number of words in the word list presented. If you present a patient 10 words, you can see high variability between lists and percentage correct. If you present 50 or 100 words, you will see less variability.

I think when you get down to the research, you find that most clinics do 20 or 25-word lists, and you can have swings of 20%, 25% list-to-list even if it's recorded, which is why the clinical utility is great, but should be taken with a grain of salt.

Dr. Jason Barnes:

How does word recognition and speech recognition differ from traditional cochlear implant candidacy assessment?

Dr. Jill Gruenwald:

Everything that we are doing in audiogram is going to be unaided with the patient's natural hearing. They are hearing those single words through headphones or through insert earphones. We can make some assumptions about who might be a cochlear implant candidate based on how many words they got correct, but to be considered a cochlear implant candidate, we need to know what you can do while aided. So using a hearing aid, bone-anchored implant, what have you.

Dr. Jason Barnes:

Is there a general rule of thumb that we follow in terms of looking at the audiogram that's performed, the PTA, and the word recognition score, that if a patient is at a certain level of hearing, that we know that more or less they're going to be a good cochlear implant candidate?

Dr. Jill Gruenwald:

That is growing. I think your traditional slam dunk cochlear implant candidates were going to have moderately severe to profound hearing loss, so pure-tone averages 70 decibels or greater, and they're going to have word recognition scores 40% to 50% percent or lower.

Dr. Jason Barnes:

Dr. Carlson, especially in research, there are different ways that we classify the severity of hearing loss. Can you walk us through those classes and how you might apply them clinically?

Dr. Matthew Carlson:

Yeah. So there's different ways you can classify hearing loss. One is what we already talked about quite a bit, and that's classifying somebody as having conductive hearing loss, sensorineural hearing loss, or mixed hearing loss. Then, secondly, you want to quantify the magnitude of the hearing loss, as we already talked about.

So normal hearing is anything less than 25 dB, mild is 25 to 40, moderate is 40 to 55, moderately severe, which is variably used, 55 to 70, and the cochlear implant range we're commonly talking about, the severe to profound, severe is 70 to 90 decibels and profound is greater than 90 decibels. As we alluded to earlier, the upper output limits of a commercial audiometer is about 120 dB, so we're not able to test beyond that. So profound is anything greater than 90 dB.

As we talked about earlier, we don't typically just say somebody has moderate hearing loss or somebody has severe hearing loss unless they have a really flat audiogram. The best thing is for the clinician just to see the audiogram. It's just a picture's worth a thousand words, but if you are going to describe it with words, it's helpful to say things like mild downsloping to moderate or moderate upsloping to mild. That might be like a Meniere's pattern hearing loss or something like that so it's more descriptive.

Or sometimes people will use phrases like a ski-slope audiogram, which indicates a precipitous decline. It's usually in the mid frequencies, around 1500 hertz. So those are the ways that people typically classify the varying levels of hearing loss.

Jill alluded to earlier, I think it's really important for us to understand as clinicians that the audiogram has a poor ability to predict who's going to actually qualify based on cochlear implant testing, two distinctly separate tests. So the audiogram and behavioral pure tones and word recognition score, which is distinctly different than the testing for a cochlear implant.

The rule of thumb that you had mentioned earlier, Dr. Gubbels has a great paper on this. Basically, 70 or 75 dB hearing loss in the low and mid frequencies and around 40% word recognition score or poor, that person has a pretty good chance of qualifying for cochlear implantation. But, again, they'll have to get the more comprehensive cochlear implant candidacy assessment with best-aided hearing.

Again, we have a whole separate podcast on this, and I encourage the listener to view this, on adult cochlear implantation, but you always want to look at the entire clinical picture. For example, adding background noise can considerably change somebody's ability to understand words. Some people compensate relatively well with background noise and other people deteriorate by even adding a little bit of background noise.

And so, when a person comes in and they say, "I know my hearing test shows that I'm doing okay, but, doc, I'm just not functioning well. You add any bit of background noise, and forget it. I'm done. I've been increasingly socially isolated. I haven't been going out. My social life is horrible," in those situations, we'll do more comprehensive testing even if audiogram doesn't indicate that their hearing loss is as significant.

I do want to mention one other thing, and we've talked about it, but I think it's a critically important aspect. That's test-retest variability, and that's on the pure tones as well as word recognition score. Also, variance in testing quality between centers on the audiogram and what that might mean for a clinician.

So it's generally accepted that a standardized audiogram, when it's performed correctly, test-retest variability between pure-tone levels is about 10 dB, and the word recognition score variability, again, is dependent on the number of words you're using in your word list. So that's test-retest variability.

The second thing I want to mention is there's been many times where we've had an outside audiogram perform and they'll come in in there. What they're describing is distinctly different than what their audiogram looks like. In those situations, particularly if we're considering the patient being an operative candidate, I'll always repeat the hearing test. I'll also use my forks to confirm it. Most commonly, we use a 512 tuning fork, and we're performing Weber and Rinne tests to help confirm our findings, particularly if we're considering operating.

Just to give you a couple examples, I've seen a person who came in with a small tumor, a vestibular schwannoma, and their word recognition score was designated 25% on their speech audiometry. They were telling me that they could use the telephone on that side and things weren't adding up. So we repeated and it was 75% hearing. That might totally change your surgical approach and what it means for the patient for the rest of their life based on that result.

The same thing can be true with sensorineural function and conductive hearing loss. If you're operating on a patient for otosclerosis, you better be sure they have a conductive hearing loss, not a sensorineural hearing loss, or else, afterwards, you're going to think you gave them a dead ear. You had a big drop in your sensorineural function, even though all along perhaps the testing was inaccurate.

You always have to look at the entire clinical picture. Use your tuning forks, repeat the audiogram, particularly if you're considering an operation on a patient. I think those aspects are critical.

Then, lastly, I'll say have a good conversation with your audiologist. I have Jill's number on speed dial. Any time a patient comes in and something's not adding up, or if she saw somebody, she'll sometimes page me and just say, "Testing wasn't really reliable. I spent a lot of time with them in the sound booth," and sometimes it's because of cognitive issues or developmental problems, but other times there might be other factors that are contributing to this test.

Remember, this is all behavioral audiometry, which is separate from what we call objective audiometry, DPOEs and ABR. DPOEs and ABR are not influenced by a person's input, they are objective testing, versus behavioral audiometry requires that a person is able to interact with you well and respond consistently.

So if you're finding things aren't adding up, repeat the testing and always consult with your audiologist who performed the test. Two very valuable insights, I think, that are worth mentioning.

Dr. Jason Barnes:

Dr. Carlson, when thinking about the reliability of an audiogram, clinically, can you test patients with a tuning fork? What's your rule of thumb regarding which tuning fork you're using and what that might mean for their hearing loss?

Dr. Matthew Carlson:

The tuning fork examination is a critical part of an otologic assessment of a patient. It can be used initially in a diagnostic capacity, as we discussed earlier. Also, the tuning fork examination is very helpful to confirm previous audiometric testing.

In otolaryngology, most commonly a 512-hertz tuning fork is used for audiometric assessment. Sometimes you'll use a 128 or 256 or a very low frequency tuning fork for evaluation, proprioception, and also confirming or evaluating superior canal dehiscence. But with regard to confirming your audiogram, you're usually talking about a 512-hertz tuning fork.

With respect to confirming your audiogram, we're specifically talking about a Weber test and a Rinne test. I think understanding how to interpret them is important, and also understanding their limitations. With the Weber test, you'll strike the tuning fork and you'll place it on an area of thin skin, most commonly on the forehead, sometimes on the bridge of the nose.

We don't usually do this because it seems cruel, but it will give you a very accurate test actually placing it right on the central incisors or just on top of the central incisors. This will give you maximal bone conduction. It should be on the midline.

The Weber test is able to distinguish a difference between the ears as small as five dB. That's what most studies will show. And so, a Weber test will lateralize to the side with better sensorineural hearing loss or the side with greater conductive hearing loss.

For example, a person with unilateral effusion who otherwise reported normal hearing weeks ago, the tuning fork would typically lateralize to the side with the conductive hearing loss. In contrast, the person who has a normal otologic examination without effusion, but you're concerned for sudden idiopathic sensorineural hearing loss, you'd expect the tuning fork to go to the contralateral side, the side with better nerve hearing.

The Rinne test is the second test we commonly talk about. That's for distinguishing air and bone conduction. So once again, most commonly the 512-hertz tuning fork is used. There's a lot of different ways providers will perform this test.

What's described in the textbook in the most standard way to perform this test is to first strike the tuning fork and hold it behind the ear on the mastoid. Again, I always say, "I'm sorry, this is going to apply a lot of pressure here, but I just really want to make sure I'm getting an accurate test."

You just strike the tuning fork, put it behind the mastoid, and you'll hold it there until the person or the patient is unable to hear the sound any longer. Then you'll remove it from the mastoid and place it just on the side of the ear canal, actually the meatus. Correctly, you're supposed to place it only two or three centimeters and nothing more than that from the external auditory canal.

If they hear the sound louder in the external auditory canal than from behind the ear, that indicates that they don't have a significant air-bone gap. In other words, it indicates that they don't have a large conductive hearing loss. If the person is able to hear the sound over the mastoid longer or better than through air conduction, that indicates they do have a conductive hearing loss. Most commonly, most references will say that if you have a test where bone conduction is greater than air conduction, that usually indicates a 15 to 25 decibel air-bone gap in most situations.

I think it's worth pointing out a couple pitfalls of this test and other ways people will perform it. But if you don't push hard enough or firm enough on a bony prominence, you won't get an accurate result, because there's attenuation or absorption of the acoustic energy or vibratory energy in the soft tissue. That's the first thing. Then when you're performing the Rinne test, if you hold the tuning fork too far away for when you're testing air conduction, you can also get an inaccurate test.

By convention, if air conduction is greater than bone conduction, which is the normal configuration, you say the test is positive. If you find out that bone conduction is greater than air conduction, by convention, you say the person has a negative test.

Just lastly, people will perform this test differently sometimes, and actually I commonly will do this. I'll say, "Which sound is louder?" and I'll strike the tuning fork hard and place it in front of their ear canal three to four centimeters away. Then I'll place it behind their ear and I'll say, "Which one is louder?"

You can also strike the tuning fork and place it in front of the external auditory canal first and wait till they can no longer hear it. Then put it on the mastoid. If they can continue to hear it on the mastoid after they couldn't ... By placing it outside the external auditory canal, that again indicates that they have a conductive hearing loss on that side.

Dr. Jason Barnes:

Along those lines, could you speak to the classifications of hearing as it pertains to research and also what we consider functional and nonfunctional hearing when we're talking about the actual patient?

Dr. Matthew Carlson:

That's a great question. Particularly when we're talking about patients with skull base disease, historically there were these classification systems. The 1995 AAO-HNS classification system for functional versus nonfunctional hearing is typically graded on class A through D. Class A and B are what we would call functional hearing or a double hearing. Then C and D are nonfunctional or non-serviceable hearing.

In that cutoff, a very easy thing to remember is the 50-50 rule. So if a person has better than 50% word recognition and better hearing than 50 dB for pure-tone average, then they have so-called functional hearing, and that would be an AAO-HNS class A or B.

In 2012, the AAO-HNS redefined what they would like reported, particularly from a research standpoint, to provide more granular results in reporting. And so, there's actually a scatter gram that's commonly used that defines a change in pure-tone levels before and after an intervention, change in word recognition score before and after an intervention, and then also defines the baseline levels.

In neurosurgery, what's commonly used is the Gardner-Robinson classification system. That's a one through five. But, fortunately, grades 1 and 2 align almost perfectly with AAO-HNS A and B. So Gardner-Robinson 1 or 2 essentially equals AAO-HNS class A or B.

That's how we typically will look at whether or not a patient has functional hearing when we're considering surgical approaches for skull base disorders. For example, if they have nonfunctional, non-serviceable hearing, we might be more inclined to perform a [inaudible 00:42:37] procedure that sacrifices hearing as part of the operation, such as a translabyrinthine approach. Again, this is a lot more nuanced than what I'm describing right now, but just as a general rule of thumb, that's what's we could consider thinking about.

I think, separately, we should also just talk about what's truly functional hearing versus nonfunctional hearing. That is what can a conventional hearing aid successfully aid for a patient who has hearing loss and what is beyond the limits of what a hearing aid can probably provide?

So, in general, again, wide variance between patients, but as a general rule of thumb, if a person has worse than 60% word recognition scores, a conventional hearing aid will provide less benefit. You can turn up the volume, but it's just going to be garbled and they won't be able to discern words accurately.

When you talk about pure-tone levels, typically the cutoff for being able to aid it with a hearing aid in the low frequencies is about 80 decibels and the ability to aid successfully in the higher frequencies is a little bit better. So you could even go up to 90 decibels, or approximately in that value, with a conventional hearing aid.

But, again, there's significant variance from patient to patient and what they'll consider good. I'll say a lot of that has to do with what their hearing is in their other ear. So if you take a person who has normal hearing in one ear and 60% word recognition in their other ear, on average, they're really going to not like their hearing aid as much because they're comparing it to the good ear.

But take, for example, a patient that has 75% word recognition in both ears, they're going to really benefit from binaural hearing aids in that situation because both ears are compromised. Again, the idea of considering the entire patient, the entire picture when you're considering clinical management.

Dr. Jason Barnes:

Moving on, I wanted to talk about tympanometry. Jill, could you tell us what is tympanometry? How do you perform tympanometry? What are the types of tympanograms that you get through these readings?

Dr. Jill Gruenwald:

Tympanometry is a great compliment to the audiogram to hopefully give the provider more information about what's going on with the middle ear. When I perform a tympanogram, I put a tip into the ear canal, and that tip uses air pressure to measure the tympanometric peak. This occurs when the pressure in the ear canal equals the pressure in the middle ear.

So a normal tympanogram will look like a mountain peak. It will look like that peak is around zero. You will see different types of tympanometry graphs. For example, if you have a completely flat line, no peak at all, we'll sometimes call that a type B tympanogram or a flat tympanogram. That can indicate stiffening of the middle ear. It can also indicate a patent PE tube or a perforation of the tympanic membrane.

You can see a tympanogram in which the peak pressure is skewed negative. We call that a type C tympanogram. That's typically eustachian tube dysfunction. Sometimes you can see that mountain peak, that tympanogram, where the peak is very high or hypercompliant. Sometimes we see a tympanogram where the peak is quite high or hypercompliant, that can indicate ossicular discontinuity, or a tympanogram where there's hypocompliance or a shallow peak, which can be stiffening of the ossicular chain as with otosclerosis.

Dr. Jason Barnes:

Can you briefly talk to us about the ear canal volume measurement and what this might mean for us clinically?

Dr. Jill Gruenwald:

In addition to the tympanic peak pressure and the compliance, you should get a number for the ear canal volume. This is a rough estimate of your canal volume, which can help you determine if there is a tympanic membrane perforation, or if there's a PE tube present, it can help you determine if that is patent or occluded.

Dr. Matthew Carlson:

I'd like to echo exactly what Jill said. Just very briefly, I think these are key things to really remember as a resident. Type A tympanogram is normal. Peak should be centered, close to zero. Type C tympanogram indicates negative pressure, usually eustachian tube dysfunction. It doesn't mean you don't have fluid. There are some people who have type C tympanograms and you'll also see air bubbles or fluid levels in there, too.

Type B small volume indicates middle ear effusion, most commonly. Type B large volume typically over 1 or 1.5 CCs indicates a tympanic membrane perforation or patent PE tube. A D tympanometry indicates hypercompliance, and that's usually indicative of two things: ossicular discontinuity or also a dimeric or flaccid tympanic membrane, if somebody's had multiple sets of PE tubes and you can see a lot of movement in it.

Then, finally, AS or A shallow indicates a more stiffened ossicular unit or tympanic membrane. That could be from tympanosclerosis, otosclerosis, et cetera.

Dr. Jason Barnes:

I next wanted to talk about the stapedial reflex or the acoustic reflex. Jill, could you tell us practically what does it look like to measure this, both the threshold and what we know as the reflex decay?

Dr. Jill Gruenwald:

The patient will have tips in each ear. One tip we refer to as the probe, and that probe is measuring the actual muscle contraction, the actual reflex. The stimulus is delivering a sound, usually of fairly loud volume. Reflex thresholds are anywhere between 70 and 100 decibels. The patient will hear the loud sound and we will measure with the probe if there is a change in acoustic admittance, a change in the energy coming back from the ear. We label the threshold at the softest sound where we see this reflex.

Dr. Jason Barnes:

Where does decay fit in here?

Dr. Jill Gruenwald:

For acoustic reflex decay, you first have to have a threshold. If you have a present threshold and if we're able to go 10 decibels louder than that threshold, we will play that sound for 10 seconds and we'll measure the strength of the reflex. If it degrades by more than 50% in that 10-second window, we call that positive for acoustic reflex to decay.

Dr. Jason Barnes:

Dr. Carlson, could you shed some light on maybe the physiology behind how this works and practically how is this used clinically?

Dr. Matthew Carlson:

Yeah. So the stapedial reflex pathway is something that's commonly tested on, and there are some things that are just better to draw out yourself and commit it to memorization, particularly before a test, et cetera. This is one of those things, almost analogous to the Krebs cycle or something like that. But I do think there are some practical applications and also some historical aspects that are at least worth mentioning.

So practically speaking, how is it used today? Most of the time people are using stapedial reflexes to distinguish conditions such as otosclerosis and superior canal dehiscence. There are some overlapping features of those two diseases. Primarily, it's the low-frequency air-bone gap that you can have, as we talked about earlier. There are some other features that help distinguish the two clinically and radiographically.

But, broadly, most of the time, before somebody will perform middle ear exploration with stapedotomy for otosclerosis, you really should have reflexes and your tuning fork should also agree with it. But your reflexes should be absent in the ipsilateral ear before you're considering the patient to have otosclerosis from a clinical standpoint versus a superior canal dehiscence, generally, your stapedial reflexes will be preserved.

Of historical relevance, we can talk about reflex decay, which we indicated earlier. There are some tips or pearls or certain patterns that might make you think the patient might have retrocochlear pattern hearing loss. Most commonly, that would be a vestibular schwannoma, but it could be a meningioma or brainstem lesion, et cetera.

So reflex decay, as initially discussed, you're supposed to think as a clinician. You're supposed to think about retrocochlear pattern hearing loss. There's something called rollover, where your ability to discern words becomes increasingly worse at higher presentation levels. So it's almost the opposite of what you'd expect. If you keep turning up the volume, you'd expect most people to score about the same or even better. However, people with retrocochlear pattern hearing loss have this phenomena called rollover, where paradoxically your word recognition score actually deteriorates.

There's something that's just generically called retrocochlear pattern hearing loss, and that is the situation where your word recognition scores are just disproportionately poor than what you might expect from a pure-tone level. For example, if somebody has 30-decibel or 40-decibel high-frequency sensorineural hearing loss and their low and mid frequencies are preserved, you would imagine that their word recognition scores would generally be quite good. However, some patients with vestibular schwannomas, for example, have a worse word recognition score, perhaps 50% or 60%, when you'd anticipate they'd have better hearing.

And so, some of these things are of historical relevance. Some of them are frequently tested on. But from a practical standpoint, mainly stapedial reflexes again are used for distinguishing otosclerosis and superior canal dehiscence.

Dr. Jason Barnes:

Another aspect of hearing tests that I wanted to touch on is when you're concerned for factitious hearing loss or non-organic hearing loss. Jill, could you tell us about some of the tests that you can consider when this is a concern?

Dr. Jill Gruenwald:

One of the first things we'll look at is the agreement between the pure-tone average and that speech recognition threshold to make sure that those two measures are aligning, that they are similar. If somebody can hear speech much better or much quieter than they can hear pure tones, we are suspicious that there might be non-organic hearing loss.

If somebody is presenting with a significant asymmetry or normal, near-normal hearing in one ear and they're offering thresholds that are quite poor in the opposite ear, we can use something called the Stenger test. This is based on the principle that if I present two similar tones to both ears at the same time, only the louder of those two tones will be perceived.

So if I take the example of someone who, in reality, has two normally hearing ears, but is perhaps offering normal hearing in one ear and moderate hearing loss in the other, I can present two tones at the same pitch. I will make it 10 decibels louder in their better-hearing ear, I will make it 10 decibels softer than they're offering in their poorer-hearing ear.

That person, if they are not being entirely honest with what's being offered on the poorer-hearing side, will hear this loud tone on the ear they have hearing loss in, "hearing" loss, and they will not push the button. However, if you had two normally hearing ears and you heard something 10 decibels better in the better-hearing ear, you would push the button.

So the Stenger test is very effective at identifying non-organic hearing loss for asymmetries. A positive Stenger means we are suspicious for functional hearing loss. A negative Stenger means we are not suspicious for functional hearing loss.

Dr. Jason Barnes:

I know there are some other objective types of hearing tests that could also help parse this out.

Dr. Jill Gruenwald:

Absolutely. We can also perform otoacoustic emissions. That is a very sensitive test of outer hair cell function. Typically, where otoacoustic emissions are present, we suspect normal or near-normal hearing. We can also measure the auditory brainstem response or ABR, which lets us estimate thresholds without relying on a behavioral test.

Dr. Jason Barnes:

Dr. Carlson, Jill, thanks so much. This has been a great comprehensive discussion of the audiologic evaluation. Before I move on to the summary, is there anything you'd like to add?

Dr. Jill Gruenwald:

No. Thank you so much for this chance.

Dr. Matthew Carlson:

I think you summed it up really well. As we talked about earlier, I would just emphasize the importance of having a good relationship with your audiology team and having a low threshold for communicating back and forth when things just don't add up, particularly when you're interpreting an outside audiogram and the need for getting additional testing to make sure it's accurate.

Dr. Jason Barnes:

Great. Well, in summary, the audiologic evaluation includes behavioral audiometry, which includes pure-tone audiometry and word recognition scores. It also includes the tympanogram and stapedial reflexes. Pure tones are obtained at different frequencies in both ears so you have an understanding of the frequency-specific hearing, which can be averaged in the pure-tone average or PTA.

Air conduction measures hearing from the external ear through the auditory nerve, while bone conduction starts at the cochlea. The difference between the two is known as the air-bone gap. The word recognition test uses a set of monosyllabic words to test understanding of words, which is presented as a percentage. Tympanometry measures the ear canal volume, as well as the flexibility of the tympanic membrane in comparison to the middle ear space, which are presented as Types A, B, and C.

Stapedial reflexes, although not used clinically as often as they were historically, measure the reflex arc of hearing, providing some information as to where a lesion might exist that is causing hearing loss. Although this mainly pertains to the middle ear currently.

In the instance of malingering or non-organic hearing loss, there are a couple of tests that can be performed. The most common of which is the Stenger test. Finally, it's essential to have a reliable audiology center and a good relationship with your audiologists, which could potentially affect clinical intervention. Jill, Dr. Carlson, thanks so much.

Dr. Matthew Carlson:

Thanks for having us.

Dr. Jill Gruenwald:

Thank you.

Dr. Jason Barnes:

I'll now move on to the question-asking portion of our time together. As a reminder, I'll ask a question, wait a few seconds to give you some time to think about the answer, and then give the answer.

First question, what are the separate magnitudes of hearing loss when we talk about pure-tone thresholds? Although there's some variability in these categorizations, generally we talk about normal hearing in an adult being less than 25 dB. Mild hearing loss being between 25 and 40 dB, moderate, 40 to 55, moderate to severe, 55 to 70, severe, 70 to 90, and profound, greater than 90.

Next question, what are some characteristic hearing loss patterns that we see on the audiogram? Some of the more common characteristic hearing loss patterns are the 4K notch, which is associated with noise-induced hearing loss, the cookie bite pattern, which is associated with congenital hearing loss, sloping high-frequency pattern, which is associated with presbycusis, the upsloping, which is associated with Meniere's, and the Carhart notch, which is a bone conduction depression at 2,000 hertz.

Next question, describe a commonly accepted pattern of asymmetric hearing loss. Although there's some controversy in this, asymmetric hearing loss is often categorized as the difference in 15 decibels over two frequencies or 10 decibels in three frequencies. Some folks characterize a word recognition score difference of 15% as asymmetric, though this isn't entirely reliable.

For our final question, describe the types of tympanometry and correlating pathologies. As we talked about, tympanometry can be type A, B, or C. Then A is broken down into AS or AD. So type AS is associated with otosclerosis and tympanosclerosis. Type AD is associated with ossicular discontinuity or a flaccid eardrum. Type B is associated with middle ear effusion or a tympanic membrane perforation if the volumes are large. Type C is associated with negative middle ear pressure or eustachian tube dysfunction. That'll be it for now. Thanks so much and we'll see you next time.