Audiometric Testing and Interpretation

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ReSound
Learning Objectives

• Perform a comprehensive audiologic assessment including air conduction, bone conduction, speech audiometry and immittance measures

• Identify the type, degree and configuration of a hearing loss

• Recommend further tests and/or the candidacy for amplification
Agenda

• Review the procedures for the following tests:
  • Case history
  • Pure-tone audiometry via air and bone conduction
  • Speech audiometry
  • Masking for pure-tone and speech audiometry
  • Tympanometry

• Along the way…
  • Interpret results
  • Discuss red flags for referral
  • Discuss candidacy indicators for amplification
Case History
Case Hx

- A questionnaire-written or verbal
- Begin **General** and **Focus** accordingly:
  - Primary complaint
  - Unilateral or bilateral presentation of symptoms
  - Time course questions:
    - How recent did x occur? Days, Weeks, Months, Years
    - How Frequently does x occur?
    - How long does x occur?
    - What treatments have you tried?
Case Hx: Medical Questions

- Highlight medical concerns and Reasons for referral (Electrophysiologic tests or balance assessment)
  - Tinnitus
  - Dizziness
  - Otalgia
  - Otorrhea
  - Hx of Otitis Media

- Exposure
  - Noise
  - Ototoxicity
  - Family History
Case Hx: Advanced Topics

- 1\textsuperscript{st} opportunity to establish rapport
- Use the case history to uncover the broader impact of hearing loss
- Uncover any self-stigmatization
- Assess technology attitudes towards hearing aids and beyond
- Help organize test procedures
Pure-Tone Testing
Pure tone audiogram

- **THE AUDIOGRAM:**

  Graphic representation of the thresholds of hearing sensitivity as a function of frequency

- “Picture of Hearing”
### Audiometric symbols

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No response symbols

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<td>ACoustIC-REFLEX THRESHOLD</td>
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Complete Pure-Tone Audiogram
Why dB “Hearing Level”

- Clinical testing is recorded in dB HL

- Hearing sensitivity in dB SPL changes per frequency

- 0 dB HL represents an intensity equal to the threshold of sensitivity of the average normal ear at each frequency.
ASHA/ANSI Threshold

- **Threshold**: Lowest intensity at which the listener can identify a signal at least 50% of the time

- Minimum responses: two out of three presentations in an ascending direction

- Threshold’s are obtained using the --“Down 10, Up 5”-- Bracketing rule (Modified Hughson-Westlake)
CLASSIC PSYCHOPHYSICAL METHODS

- METHOD OF LIMITS
  - Most like Bekesy Audiometry

- METHOD OF ADJUSTMENT
  - Developed by Fechner with the tester in control

- METHOD OF CONSTANT STIMULI
  - Stimuli presented at random limits
ASHA (1978) Method

- Start by presenting a tone at 30 dB if hearing is suspected to be normal
- If hearing loss is suspected or no response start at 50 dB
- If no response increase in 10 dB steps until response is obtained
- Once positive response is obtained begin down 10 dB up 5 dB bracketing
Air Conduction (AC) and Bone Conduction (BC)

- **Air conduction**: Transmission of sound via an earphone or speaker through the outer and middle ear to the cochlea

- **Bone conduction**: The transmission of sounds to the cochlea by vibration of the skull
Air Conduction Transducers

- TDH39 or TDH49 earphone mounted in a telephonics 51 or MX-41AR cushion. (per ANSI S3.6-2004)

- **DISADVANTAGES:**
  - Possible leakage of ambient noise (only an issue when testing outside a booth)
  - Possibility of collapsing ear canal
  - Reduced interaural attenuation
  - Creation of occlusion effect
  - Frequency response up to 8 kHz
Insert ear phones/ER 5A or 3A

- **Insert phones** are superior because of:
  - increased interaural attenuation
  - infection control
  - reduces problem/occurrence of collapsed ear canals
  - overall comfort
Bone Conduction Oscillator

- BC testing is conducted with an oscillator that consists of a vibratory unit housed in an ANSI standard plastic unit mounted to a headset.
- The most common bone conductor is called a Radioear B-71.
- The oscillator is calibrated so that it produces pure tones of the same intensity and frequency as those used in air conduction.
BC output limits

- Output for BC is less than AC
- LF less than HF
- BC not reliable above 4K

- Limits: 250–approx 35 dB, 500 approx 50 dB, 750-4K around 65 dB (if you go higher, a vibrotactile (VB) response is likely)
- VB response: When patient can feel vibration output from the BC stimulation
Audiogram Interpretation
The Audiogram

- When looking at an audiogram, you should see:
  - Degree of loss
  - Type of loss
  - Configuration of loss
Normal Hearing: Pure-tone audiometry

- When air conduction (AC) and bone conduction (BC) thresholds are within normal limits.
  - Normal threshold for an adult: 0-25 dB
  - Normal threshold for children: 0-15 dB
- AC and BC thresholds should be within 10 dB
Degree of loss
Conductive Hearing Loss

- Air conduction thresholds will be 25 dB level or higher. Bone conduction thresholds are within normal limits of 0-25 dB
- **Air-bone gap** – When there is a 10 dB (or greater) difference between AC and BC thresholds
- Can be candidates for amplification after medical consult
Sensory-Neural Hearing Loss (SNHL)

- AC and BC scores will be greater than 25 dB and the AC and BC will be within 10 dB
- SNHL does not indicate where the problem lies
- Rule out neural problems with advanced diagnostics
- Many are excellent candidates for hearing aids
Mixed Hearing Loss

- Contains both sensory-neural and conductive components
- AC and BC thresholds are 25 dB or greater
- An air-bone gap of greater than 10 dB
- Can be candidates for amplification after medical consult
CONFIGURATION OF HEARING LOSS

- Flat – Little or no change in thresholds (+ or – 20 dB) across frequencies
- Sloping – As frequency increases, the degree of hearing loss increases.
- Rising – As frequency increases, the degree of hearing loss decreases.
- Trough (cookie bite) – The greatest hearing loss is present in the mid frequencies; hearing sensitivity is better in the low and high frequencies
Loudness Perception

- MCL: Most comfortable loudness
- UCL: Uncomfortable Loudness Level/ LDL: Loudness discomfort level
  - Typically obtained with running speech
  - Bracketing procedure used
- UCLs tend to be slightly higher when they are measured upon repeated trials
  - Need to be completed for amplification
  - Dynamic range: threshold to UCL
  - Reduced in cochlear hearing loss
Speech Audiometry
We use Speech to test hearing....

- Pure-tones, or Narrow Bands of Noise, don’t have much “value” in the real world
- Identifying a pure-tone is a low-level auditory task
- Speech testing can provide:
  - Improved sensitivity to various pathologies
  - Addresses symptoms of “Can hear but can’t understand”
  - Provides info regarding higher auditory functions
Speech Reception Threshold
Speech Reception Threshold (SRT)

- Lowest intensity level at which 50 percent of spondaic words can be recognized

- In the SRT, the patient must repeat two-syllable words, which are typically presented via monitored live voice (MLV)

- Most popular:
  - Airplane, baseball, cowboy, farewell, greyhound, hardware, iceberg, mousetrap, mushroom, northwest, oatmeal, playground, railroad, sidewalk, stairway, sunset, toothbrush, whitewash, woodwork, workshop
2 Purposes of the SRT

- Provides intertest reliability check between pure tone and speech threshold
  - Good Agreement: within 6dB
  - Fair Agreement: within 7 to 12
  - Poor Agreement: greater than or equal to 13.

- Provides a starting point for determining the level to begin a suprathreshold test, such as word recognition
SRT Method

- Familiarize patient (closed set)
  - Face to face, suprathreshold
  - Assess patient’s ability to hear with few acoustic cues—this is why it’s “okay” to guess
  - Live voice is acceptable because response is primarily to intense vowel sounds (equated by peaks on VU meter)
  - Carrier phrase does not effect SRT
SRT Method Continued

- **ASHA:**
  - Present at 30-40dB above estimated SRT
  - Present a word at the starting level and decrease in 10 dB steps for each correct response
  - If an incorrect word is repeated, present another word.
  - If the 2nd word is correct continue dropping by 10 dB
  - When 2 consecutive incorrect responses are obtained. Increase 10dB and Begin 2 word, 2 dB step decrements until 5 out of six incorrect words are obtained
  - Subtract the number of correct responses from the starting level and add a 1 dB correction factor.
  - Most audiologists use a 5 dB approach-requiring a 2 dB correction factor.
SRT Method

- Martin and Dowdy 1986:
  - Begin at 30 dB, if no response 50 dB, if still no response increase by 10 dB until response is obtained
  - Use bracketing method similar to PT Testing
  - Threshold is defined as lowest level with 3 correct responses
  - Most clinicians use this method
Word Recognition Testing
Speech Recognition/Word Rec

- Suprathreshold

- Patient is asked to recognize monosyllabic word and repeat

- Presented by recorded voice (CD)
  - When attempting to compare clinics or normative data, recorded words are absolutely necessary

- NU6, CID W-22
Purposes of Speech Recognition Testing

- Individuals with similar hearing thresholds may demonstrate very different speech processing abilities
  - Assessment of speech perception performance
    - Potential diagnostic value for retrocochlear lesions
    - Planning and management in audiologic habilitation
    - Prediction of performance
      - Hearing aid benefit
Methods and Interpretation
Presentation level

- Suprathreshold
  - Average conversational speech (50-55 dBHL around 70 dB SPL)
  - MCL
  - Presentation levels are usually 25, 30-40 dB SL re: SRT
  - 95 dB SPL—75 dB HL
  - SL rel 2 kHz
  - UCL-5 dB
  - prob: slope of the hearing loss
Test List Size

- Most standard speech recognition tests include 50 monosyllabic words
- Many clinicians use 25
- W-22 can be ranked (first 10 are most difficult) Runge and Hosford-Dunn (1985)
  - Give first 10 – all correct stop, 1 or more wrong, give next 15
  - If less than 4 are missed in first 25, stop
  - Otherwise complete all 50
Interpretation
Interpretation

• Word recognition testing has regularly been used in the differential diagnosis of retrocochlear disorders

• Asymmetries in word recognition scores between the ears is the hallmark sign for referral for advanced tests

• How much of a difference is significant?
Length of Word Lists

• Reliability improves as number of test items increases

• Speech recognition scores become more variable (less reliable) as they go from either extreme 100 to 0 (toward 50%)

• 20 % difference will be significant relative to 95% confidence limits if a 50 word list is used

• Use 25% for 25 word lists
SPRINT Chart
Word Recognition in Noise Tests

- Word recognition tests in quiet are a weak predictor of hearing aid benefit
  - Quiet-rarely happens in the real world
  - Words in isolation
- Word recognition tests in noise are a better predictor
  - Hearing In Noise Test (HINT)
  - Quick Speech-In-Noise (SIN)
    - Use sentences with keywords for scoring
    - Presented with background noise of varying levels
Masking
Masking

- When the threshold of hearing for one sound is raised by the presence of another (masking) sound

- Used when large asymmetries between ears are present
  - Keeps the non-test ear “busy”

- Like when using a map to navigate
  - Many different ways to get from point A to point B

- Rules based on assumptive logic
Terminology

- **Test Ear**- (TE) the ear receiving pure-tone stimulus during AC or BC testing

- **Non-Test Ear**- (NTE) the ear that is not intentionally receiving the pure-tone stimulus

- Masking in the NTE is needed *if it is assumed* a sound stimulus presented to the TE reaches the NTE
Crossover

- When a signal is presented to the test ear at an intensity great enough to stimulate the non-test ear.

- Masking is necessary whenever the possibility of crossover exists.

- Crossover route for air conduction signals occurs by bone conduction to the cochlea of the opposite ear.
Shadow curve

- Results when masking is not used
- When thresholds from the ear with the greatest amount of hearing loss mimic threshold from the normal or better hearing ear.
Interaural Attenuation

- Amount of energy lost during the crossover

- Helps predict how much has “crossed over”

- Values for AC vary as a result of:
  - subject variability (skull properties etc.)
  - frequency of the test signal
  - earphone transducer type

- IA for BC = 0 dB theoretically, no energy is lost
When?: 2 General rules of Thumb

• 1.) **Supra-Aural Earphones:** When a difference between the BC threshold of the NTE and the AC threshold of the test ear of 40 dB

• 2.) **Insert Earphones:** When a difference between the BC threshold of the NTE and the AC threshold of the test ear of 60 dB

• **Shortcut:** Mask when a 40 (earphones) or 60 (inserts) dB difference between ears

• **If a conductive loss is suspected use a conservative estimate**
Visualization

75  65  5  5
When to mask: BC

- Mask when ABGs of more than 10 dB are present

- An ABG of 10 dB or less is considered to be too small for clinical purposes
Types of masking noise

- **Narrow band noise** – Band-pass filtered noise centered around a specific frequency.—used in PT Audiometry

- **Speech noise** – Broadband noise with approximately equal energy per octave below 2000 Hz.
  - Speech noise is also referred to as “pink noise”
    - Speech noise is filtered to look like the speech spectrum
How much masking?

- **The following formulas only give you the starting masking level**
- AC EM (effective masking) starting level = AC threshold of NTE + Safety factor (15 dB)
- BC EM starting level = AC threshold of NTE + Safety factor (15 dB) + Occlusion effect

- The occlusion effect is equal to 20 dB at 250 Hz; 15 dB at 500 Hz; 10 dB at 750 Hz; and 5 dB at 1000 Hz.

- **Note:** Don’t include the occlusion effect if you have an air-bone gap greater than 10 dB in the non-test ear.
The Under/Over

- **Under masking**: Masking levels below the minimum amount of masking needed in the NTE to prevent the possibility of crossover to the TE

- **Over masking**: Levels presented to the NTE that is loud enough to cross over and mask the TE
Plateau method (Hood, 1960)

- Widely accepted way of finding masked thresholds

- The plateau occurs when the NTE is effectively masked by the noise so that the tone is heard by only the test ear

- The masking plateau range of effective masking is the intensity range between the minimum necessary masking level and the maximum permissible masking level
Plateau procedure:

• Present pure tone to TE at previously established threshold

• Introduce masking to the NTE (initial level calculated from NTE threshold)

• Re-establish threshold (some do at end)

• If PT threshold remains the same, increase masking level by 5 dB

• If no response, increase the presentation level to the TE
Plateau

- Occurs when the threshold level does not change as the masking level increases from minimum to maximum.

- A threshold shift will only occur when the non-test ear threshold was contributing to the response.
The masking plateau

- The masking plateau can be narrow or wide
  - The wider the air-bone gap, the smaller the plateau.

- The wider the plateau, the more confidence you can have in the validity of the mask threshold.

- Most audiologists typically require a plateau to be at least 15-20 dB before accepting it as valid.
Masking: Speech Audiometry
Masking: Speech Reception Threshold

- When the presentation level in the TE exceeds the best bone conduction threshold of the speech frequencies in the NTE by 40 (earphones) or 60 (inserts) dB HL

- Some look at average BC in speech freq

- Short cut: mask when SRT of TE exceeds SRT of NTE by 45 dB or more

- Formula: $\text{SRT EM} = \text{Presentation level (TE SRT)} - 35 \text{ dB} + \text{ABG of NTE}$
Masking: Word Recognition

- When presentation level of the TE exceeds the best bone conduction threshold of any of the speech frequencies by 35 dB or more

- Shortcut: mask when the presentation level in the test ear exceeds the SRT in the NTE by 35 dB or more

- Formula: \( WR\ EM = PL\ of\ TE - 25 \) plus ABG of NTE
Tympanometry
Middle Ear System: Pathology Overview

- Middle Ear System – “Tuned” for sound transmission
- Mass and Stiffness characteristics
- Pathologic Conditions- Alter the characteristics
- Tympanometry useful in assessing the status of the middle ear system
Instrumentation
Instrumentation

- Y-226 tympanometry

- Probe tip-rubber “earplug” sits on top of the probe creates a hermetic seal

- Probe tip with 3 lumen connected to:
  - Manometer-pressure change
  - Receiver-probe tone
  - Microphone-Measure SPL as pressure changes
Components of a Y-226 Tympanogram

- **Tympanic peak pressure**
- **Static Admittance**
- **Equivalent volume**
- **Tympanic Width**
Tympanic Peak Pressure
Tympanic Peak Pressure

- The tympanic peak pressure: daPa at which the peak of the tympanometric curve occurs

- Normal ME pressure is typically at 0 +/- 100 daPa
Tympanic Peak Pressure

Tympanic peak pressure

Y = 0.52 mmho

Y = 0.45 mmho

Veq = 0.4 mmho

TW = 80 daPa
Tympanic Peak Pressure

- Infection can cause swelling of the mucosa of the nasopharynx reducing or eliminating ET function

- TM retracts- The pressure in the middle ear becomes negative relative to the air pressure lateral to the TM

- Negative middle ear pressure is associated with Eustachian tube dysfunction
Equivalent Ear Canal Volume
Equivalent Ear Canal Volume

- The volume of air between the probe tip and the TM
- Provides little diagnostic/physiologic data

- A flat tympanogram with a large or small ECV can indicate:
  - Large volume: eardrum perforation or open PE tubes
  - Small volume: wax blockage

- Flat tymp with normal volume cannot completely rule out perforation due to active disease
Equivalent Ear Canal Volume

V_{eq} = 0.4 \text{ mmho}

Y = 0.52 \text{ mmho}

Y = 0.45 \text{ mmho}

TW = 80 \text{ daPa}
Equivalent Ear Canal Volume

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<td>* 1.0 cm³</td>
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<tr>
<td>ADULTS</td>
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*Margolis et al., 1997 based on 3-6 year old children
Equivalent Volume

- If volume exceeds upper limits suggests perforation or patent PE tubes

- Compare ears when unsure if abnormal volume is representative of variation or pathology

- Default reading probe tip lumen obstruction is 7.0

- Cerumen is not a contraindication for tympanometry
  - Use to determine if cerumen may impact behavioral results
Static Admittance
Static Admittance

- Static admittance - the height of the tympanometric curve measured at the plane of the TM.

- Static - measured at the tympanic peak pressure

- Height relative to chosen tail of tympanogram
Static Admittance

Y = 0.52 mmho

Veq = 0.4 mmho

TW = 80 daPa

Y = 0.45 mmho
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Static Admittance

- **Static admittance below the lower limit measures**
  - Reduced static admittance
  - Associated with a stiff middle ear system
  - Middle ear fluid or a fixed stapes

- **Static admittance above the upper limit**
  - Abnormally high static admittance
  - Hyper compliant middle ear system
  - Associated with a monomeric TM
  - Mass dominated
Tympanic Width
Tympanic Width

• Width of the tympanogram in daPa measured at half the height of the tympanogram.

• Quantifies shape of the tympanogram
  • Wide tympanic width is associated with middle ear pathology

• Combination of normal ME pressure and wide tympanic width is a good diagnostic sign for a middle ear problem
Tympanic Width

- $Y = 0.52$ mmho
- $V_{eq} = 0.4$ mmho
- $TW = 80$ daPa
## Tympanic Width Criteria

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Describing Tympanograms

- Use measured values for TPP, static admittance, equivalent ear canal volume compared to normative data
- Relate tympanometric results to other results
- Jerger types- used a letter to indicate the overall shape of the tympanogram.
Tympanometry Limitations

- A unique pattern does not exist for every possible ME pathology

- The most lateral pathology has a dominant effect on the measurement
  - Multiple middle ear pathologies can exist in the same ear

- Variability in tympanometry interpretation

- Tympanometry should be used in conjunction with other measures.
Summary

- Perform a comprehensive audiologic assessment including air conduction, bone conduction, speech audiometry and immittance measures
- Identify the type, degree and configuration of a hearing loss
- Recommend further tests and/or the candidacy for amplification