Basics of Audiology

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Disclosure

- Jen Repovsch Au.D. is an employee of Maico-Diagnostics, a manufacturer of hearing testing devices.

Learning Objectives

- Describe several types of audiology tests and their use.
- Identify what portion of the auditory system each test evaluates.
- Perform basic audiology tests such as audiometry, tympanometry, and OAE's.
- Record, describe and understand results of basic audiology tests such as audiometry, tympanometry, and OAE's.
Basics of Audiology

• Presentation Overview:
  – Review of the ear and hearing
  – Audiometry & the Audiogram
  – Tympanometry & the Tympanogram
  – Otoacoustic Emissions (OAE’s)

– Hands-on workshop:
  • Screening audiometer
  • Diagnostic audiometer
  • Tympanometer
  • Otoacoustic Emissions

WHY TEST HEARING?

Statistics (Children)

• Est. 2-3 out of every 1000 babies born with significant hearing loss
• 50% of those with hearing loss have no risk factors

National Institutes of Health

Consequences of undiagnosed loss in infants and children:

• Language development
• Cognitive development
• Social development
Statistics (Adults)

- Est. 1 in 3 people has a hearing impairment (65-74 age group)
- Est. 1 in 2 (75+ age group)

Consequences of undiagnosed hearing loss in Adults:
- Social Withdrawal
- Depression
- Decrease in quality of life

Importance of Testing Hearing

- Hearing Loss, in and of itself, can have a detrimental affect on life, and can easily go undetected.
- Important to screen or evaluate hearing throughout life (Ex.: newborn screening, school-aged screening, adult screening, etc.).

The Ear and Hearing
The Normal Ear

- The Ear has 3 sections. The outer ear, the middle ear, and the inner ear.

How the Normal Ear “Hears”

- The outer ear consists of the part of the ear you can see, called the Pinna, and the ear canal.
- Sound waves travel through the air and reach the outer ear.
- The Pinna’s main job is to funnel the sound into the ear canal to the Ear Drum.

How the Normal Ear “Hears”

- When sound waves reach the Ear Drum, or Tympanic Membrane, they are now at the Middle Ear
- Sounds strike the ear drum and cause it to vibrate the smallest bones in your body, the Ossicles.
- The Ossicles act as a link between the outer ear and the inner ear.
How the Normal Ear “Hears”

- The inner ear contains the cochlea and the semi-circular canals.
- The semicircular canals’ main function is balance.
- The Cochlea is the “end organ of hearing.”

How the Normal Ear “Hears” (continued)

- The inner ear is a fluid-filled cavity full of nerves called Hair Cells.
- Hair Cells come in two varieties and have two main functions.
  - Outer Hair Cells: Receive and Detect sounds.
  - Inner Hair Cells: Transmit sounds to the brain.
- Vibrations from the Ossicles create a “wave” in the inner ear fluid that stimulates the hair cells.

A Word About Hair Cells

- Hair Cells are the reason that we can detect and understand sounds.
- The hair cells are set up “tonotopically” in the cochlea, in other words, like a piano...in order of tones.
A Word About Hair Cells

• This is an electron microscope photograph of normal hair cells. Very organized.

Auditory signal changes

– Air Molecules carry the sound vibration
– Sound hits ear drum and becomes a mechanical vibration
– Stapes moves fluid in the cochlea and the signal is now a fluid mechanical vibration
– Hair cells on Basilar membrane are bent due to traveling wave and generate the electrical potential.
– Nerve fibers carry the signal along the 8th cranial nerve through the brainstem to the cortex.

The Impaired Ear

• There are 3 types of Hearing Loss:
  – Conductive ~ Abnormality of the outer or middle ear. Usually temporary and medically treatable.
  – Sensorineural ~ Damage to the inner ear or nerves of hearing. Usually permanent.
  – Mixed ~ Both Conductive and Sensorineural
The Impaired Ear (Conductive Loss)

- Conductive hearing loss occurs when there is a disruption of the transmission of sound (Ex: fluid in the middle ear)
- Typically occurs in the outer or middle ear
- Cochlea and CN VIII are still in tact
- Many times, this is a temporary loss that can be treated medically

The Impaired Ear (Sensorineural Loss)

- Sensorineural Hearing Loss occurs for many reasons
- Starting from the age of 20, The Hair Cells slowly begin to deteriorate
- Hair Cells can also be damaged from loud noises, medicine, head trauma or other causes
- Most Sensorineural Hearing Losses are due to natural loss of hair cells

The Impaired Ear

- This is an electron microscope photograph of damaged hair cells.
- When hair cells are damaged, they cannot be repaired or replaced.
Audiometric Evaluation

- Several tests may be used in combination to look at different parts of the auditory system depending on the patient:
  - Otoscopic Exam
  - Pure-tone Audiometry
  - Speech Audiometry
  - Tympanometry
  - Acoustic Reflexes
  - Acoustic Reflex Decay
  - Otoacoustic Emissions
  - Auditory Brainstem response

Audiometry

The entire auditory pathway

- Subjective test – verbal or physical response
- Tests all parts of the ear – the entire auditory system
  - Pure Tone
    - Air conduction
      - Headphone, Insert Earphone, Speaker
    - Bone conduction
  - Speech testing
- Generate an Audiogram
Basic Pure-tone Audiometry

• Measures hearing sensitivity
  – Air conduction → measures sensitivity of entire pathway of auditory system, including outer, middle, and inner-ear.
  – Bone conduction → "by-passes" outer and middle-ear to measure sensitivity of inner ear directly.
• Determines type and severity of hearing loss
• Results are used to generate the audiogram

Audiogram

• Mark Air and Bone thresholds on the chart
  – O Right ear
  – X Left ear
  – • Right Bone (unmasked)
  – ▲ Left Bone (unmasked)
• Behavioral response - cooperation of the patient is important

Types of Hearing loss

• Hearing Loss is described as a range
• Ranges from Mild through Profound
Types of Hearing Loss

- **Conductive Hearing loss**
  - Primarily caused by damage to the outer or middle ear
  - Bone conduction is within the normal range, Air Conduction is not

- **Sensorineural**
  - Damage to the Cochlea or beyond

- **Mixed Hearing Loss**
  - Has both conductive and sensorineural components
Conducting a Test

**Air Conduction**
- Place headset centered over ear canals and band snug on top of head
- Red on Right ear, Blue on Left ear

**Bone Conduction**
- Place bone oscillator on mastoid bone with other end of headband on opposite temple.
- Make sure oscillator does NOT touch the ear.
- Bone conduction stimulates BOTH ears.

Finding a Pure-Tone Threshold
- Instruct patient that they will hear tones. Some will be very soft. Press the button (or raise hand) every time they hear the tone, even if it is very soft.
- Start at 1000Hz at 30dBHL in better ear (or right ear) and present the tone.
- Follow “Down 10, Up 5” rule:
  - If patient responds, decrease 10dB
  - If patient does NOT respond, increase 5dB
  - Follow this pattern until 2 out of 3 responses are obtained at the same level on the ascending run.
- Repeat this procedure for all test frequencies: 2000, 4000, 8000, (repeat 1000), 500, 250Hz.

Conducting a Screening
- Usually performed at the boarder of normal hearing. (ex: 20dBHL)
- Screen 500, 1000, 2000, 4000Hz at 20dBHL.
- Present each tone at least twice.
- Patient either hears it or not.
- If miss any tone in either ear, refer for full evaluation.
Basic Speech Audiometry

- **Speech Reception Threshold (SRT):**
  - Softest level at which familiar speech can be recognized 50% of the time.
  - A cross-check: correlates with pure-tone average (thresholds at 500, 1000, 2000Hz)
  - Similar procedure used to obtain threshold, except use Spondee words instead of tones.

- **Word Recognition Score (WRS):**
  - Percent correct of a given standardized speech list presented at a comfortable conversation level to the patient.
  - A measure of speech understanding under ideal listening conditions; however, speech tests may be done in noise as well (Ex: QuickSIN, HINT, etc.)

Example Pure-tone and Speech Audiometry

Normal hearing from 250-1000Hz, sloping to a moderate sensorineural loss in the right ear.

- Speech Recognition Threshold (SRT): 25dBHL
- Word Recognition Score (WRS): 90% at 70dBHL

Speech & the Audiogram

- Speech sounds in the English language can also be plotted on the audiogram.
- This gives some insight into what sounds the patient is missing in everyday conversation.
Speech & the Audiogram

Example

- This patient has normal hearing in the low frequencies and will have no trouble with low frequency speech sounds.

- Sloping loss in the higher frequencies will make it difficult to hear consonant sounds such as “k”, “t”, “s”, & “th” at a normal conversation level.

Why Use Audiometry?

- The “standard” hearing test.
- Determine frequency specific hearing sensitivity.
- Determine speech understanding in quiet and in noise.
- Audiogram and speech understanding are valuable counseling tools.
- Audiometric thresholds used to fit hearing aids.
- Screening or diagnostic protocol can be used.
- Can test children and adults.

Summary--Audiometry

- Subjective evaluation to diagnose hearing loss
- Evaluates the entire auditory system
- Provides information on the most appropriate “next step”
  - Further diagnostic testing
  - Medical intervention
  - Hearing aids
Tympanometry

The Middle Ear

- Objective measure of the middle-ear system
- “Not a hearing test”
- Graphic representation of ear compliance in relation to the pressurization of the ear canal
- Objectively demonstrate the mechanical-acoustic characteristics of the outer and middle ear
- Measures the ease in which energy flows through the system

Tympanometry

- A probe is inserted in the ear canal that contains a loudspeaker, a microphone, and a pump.
- A tone (226Hz) is delivered into the ear while the pressure is changed within the sealed canal.
- Measurement taken at the probe - plots the flexibility of the TM and the ossicles.
- Plot is displayed in a graph called the tympanogram
So the Tympanogram tells us....

- Middle-ear pressure
  (normally equal to atmospheric pressure)
- Ear canal volume
- Compliance of middle-ear system (eardrum movement)

**Tympanogram**

- Shape of the tracing gives diagnostic information regarding the function of the middle ear
- “Normal” middle ear function is a range represented by the box
- The tracing is interpreted and labeled as a type – A, B, C

**Sample Normative Data**

<table>
<thead>
<tr>
<th>Children (age 3-5 yrs)</th>
<th>Peak Comp (mL)</th>
<th>Ear Canal Vol (mL)</th>
<th>“Tymp Width” Gradient (daPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>0.5</td>
<td>0.7</td>
<td>100</td>
</tr>
<tr>
<td>90% range</td>
<td>0.2-0.9</td>
<td>0.4-1.0</td>
<td>50-500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adults</th>
<th>Peak Comp (mL)</th>
<th>Ear Canal Vol (mL)</th>
<th>“Tymp Width” Gradient (daPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>0.8</td>
<td>1.1</td>
<td>80</td>
</tr>
<tr>
<td>90% range</td>
<td>0.5-1.4</td>
<td>0.6-1.5</td>
<td>50-100</td>
</tr>
</tbody>
</table>

Data above from Margolis and Heller (1987)

Pressure typically considered normal in the range of -150 to +25 daPa
Types of Tympanograms

**Type A**
- Normal middle ear pressure
- Normal eardrum movement
- Normal ear canal volume

Example:
- Normal middle ear

**Type A<sub>s</sub>**
- Reduced Compliance
- Normal Middle-ear pressure
- Normal ear canal volume

Example:
- Fixation of ossicles
- Scarring on TM
**Type A**

- Increased compliance
- Normal middle-ear pressure
- Normal ear canal volume

Example:
- Disarticulation of ossicles, Monomeric tympanic membrane

**Type B (normal volume)**

- "Flat"
- No compliance or pressure peak indicated
- Normal ear canal volume

Example:
- Middle-ear fluid

**Type B (increased volume)**

- "Flat"
- No compliance or pressure peak indicated
- Increased ear canal volume

Example:
- Perforated TM
- Patent P.E. Tubes
Type B (decreased volume)

- "Flat"
- No compliance or pressure peak indicated
- Decreased ear canal volume

Example:
- Occluding Wax
- Probe up against canal wall??

Type C

- Excessive negative middle-ear pressure
- Normal or reduced compliance
- Normal ear canal volume

Example:
- Eustachian tube dysfunction, initiation or resolution of middle-ear fluid
- "Sniffling" children

The Infant Ear

- The anatomy of the infant ear is different to the adult ear.
  - Size of outer ear, middle ear and mastoid
  - Mass changes of the middle ear due to bone density, and mesenchyme
  - Change of the membrane system
  - Formation of the bony ear canal wall.
  - Changes in ossicular joints
Infant Ear continued...

- The infant ear is mass dominated.
- The infant ear has a lower resonance frequency, therefore lower probe tones create complex patterns and more notching.
- Classification scheme not consistent with pathology
  - Example, Type A recorded with effusion
- Using a 1000Hz probe tone is optimal.

So for infants under 7 months....

- Using a 1000Hz probe-tone is optimal
  - More consistent with Middle-Ear Effusion
- Look for any discernable peak

Advantages of Tympanometry

- Objective measure of middle-ear function
- Fast & Easy to perform
- Requires no response from the patient
- Can be performed on all ages, infant to adult
Why Use Tymps?

- Objective documentation of reduced eardrum movement (ie: fluid, wax, etc.)
- Monitor chronic middle-ear fluid
- Monitor P.E. tube function
- Confirm tympanic membrane perforation
- Monitor Eustachian tube function
- Correlate with audiogram to develop a more complete picture of hearing

Otoacoustic Emissions (OAE’s)

Inner ear (cochlea): Outer hair cells

Otoacoustic Emissions

Objective measure of the integrity and function of the outer-hair cells of the cochlea.
Otoacoustic Emissions (OAEs)

- OHC (Outer Hair Cells) have active properties which increase energy in the cochlea.
- This motility enhances hearing sensitivity and frequency selectivity.
- OAEs - Low-level sounds generated by the outer hair cells of the cochlea (inner ear) in response to auditory stimuli.

Mechanics of OAE

- A probe is inserted in the ear that contains a speaker(s) and a microphone.
- A sound is presented in the canal and propagated through the hearing mechanism to the cochlea.

Mechanics of OAE

- Healthy outer hair cells produce sounds in response to the stimulus that are propagated back out of the cochlea, through the middle ear to the ear canal.
- The microphone measures these small responses (OAEs) in the ear canal.
Types of OAEs

• Most commonly used in the clinic:
  
  – Transient Evoked OAE (TEOAE)
    • Stimulated usually by a click
    • Measured in the time domain after the stimulus
  
  – Distortion Product OAE (DPOAE)
    • Stimulated by 2 tones (f1&f2)
    • Intermodulation distortion produces 3rd tone that is measured as OAE.

Factors in Measurement of OAE

2-way transmission
Noise

- Ambient or environmental noise
- Patient Noise
  - Breathing
  - Movement
  - Swallowing/sucking
- Equipment noise
  - Excessive rubbing/movement of the probe cable

Probe fit

- Deep probe insertion is essential
  - Inverse relationship between canal volume & OAE stim/response
    - Also helps reduce external noise

Selecting an Eartip

- Maximum OAE amplitudes are achieved with a deeply sealed eartip
- Shallow placement of the eartip in the ear canal reduces both the stimulus level and the measured level of the emission
- Appropriate selection of eartip improves with experience
Tips on Selecting an Eartip

- The eartip should fit snugly
- The tester should **not** hold the eartip in the ear during testing
- To verify a deep insertion, only 2-3mm of the eartip should be visible

Placing the eartip on the probe

- It is extremely important that the eartip be fully seated on the probe tip
- There should be no gap between the base of the eartip and the body of the probe
- Improper placement of the eartip can result in stimulus levels being reduced by 10-12 dB, producing perhaps a 5 dB reduction in emission level

Inserting the Eartip (Children & Adults)

- Have patient sit quietly
- Gently pull up on the top of the ear
- Visualize the opening and gently insert eartip in the direction of the canal
- Start the test on the device. Test will run automatically.
What Does the Measurement Look Like?

OAE’s & Sensory Hearing Loss

- Sensory Hearing Loss
  - When the middle ear is normal, OAE measurements allow us to determine cochlear function in isolation from the rest of the auditory pathway

Advantages

- Screening or diagnostic application
- Highly sensitive
- Site specific (Outer Hair Cells)
- Do not require behavioral cooperation or response (objective)
- Ear specific
- Highly Frequency specific (DP)
- Do not require a sound treated environment
- Can be very quick (>30 sec)
- Portable
- Relatively inexpensive
Limitations

- Susceptible to effects of noise
- Affected greatly by middle ear status
- Only info about Outer Hair Cells
- May be absent or abnormal with normal audio
- Not detectable with hearing loss > 40 dB
- Not a measure of neural or CNS auditory function
- Not a test of hearing

Summary—OAE’s

- OAEs are highly sensitive to changes in the cochlea that also alter auditory sensitivity
- OAEs are sensitive to middle ear pathology
- OAEs are present in nearly all normal-hearing ears
- Absent/abnormal OAEs indicates sensory hearing loss and/or middle ear pathology

Putting It All Together
Putting Everything Together

Example Results for Different Types of Losses

<table>
<thead>
<tr>
<th>Type of Hearing Loss</th>
<th>Auditory exam</th>
<th>Type</th>
<th>OAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>WNL</td>
<td>Type A</td>
<td>WNL</td>
</tr>
<tr>
<td>Conductive</td>
<td>Hearing Loss with a bone gap</td>
<td>Type B</td>
<td>Absent</td>
</tr>
<tr>
<td>Sensorineural</td>
<td>Hearing Loss in the inner ear</td>
<td>Type A</td>
<td>Reduced or absent (inner configuration at midnight?)</td>
</tr>
<tr>
<td>Mixed</td>
<td>Hearing Loss in the inner ear and a bone gap</td>
<td>Type A</td>
<td>WNL</td>
</tr>
</tbody>
</table>

Each test adds a little piece to the puzzle. A full evaluation can then help put all the pieces together...

Time to Conduct Some Tests!

Screening Audiometry
Diagnostic Audiometry
Tympanometry
OAE's
References


