Audiology 101-A & B: Introduction to audiology for non-audiologists working in and supporting EHDI activities

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Disclaimer

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Audiology 101 A & B

• Identify the parts of the auditory system
• Describe how the ear works
• Describe the types and degrees of hearing loss
• Describe how hearing loss is assessed and diagnosed
• Describe the types of treatment and intervention for hearing loss
What are Audiologists?

Specialists in **Hearing and Balance**

- Prevention of hearing loss
- Identification and assessment of hearing and balance problems
- Rehabilitation of persons with hearing and balance disorders
Parts of the Auditory System

- Outer Ear
- Middle Ear
- Inner Ear
- Central Auditory Nervous System
Outer Ear

- Pinna
- External Auditory Canal (Ear Canal)
- Tympanic Membrane (Ear Drum)
Tympanic Membrane (Ear Drum)
Middle Ear

Ossicles (bones)

Eustachian Tube
Middle Ear Ossicles (bones)
Inner Ear

Cochlea
• Organ of Corti
• Hair Cells
Organ Of Corti

- End organ of hearing
- Fluid movement causes bending of nerve endings
- Nerve impulses (electrical energy) are generated and sent to the brain

(From Augustana College, “Virtual Tour of the Ear”)
Hair Cells

- Frequency-specific
- 3 rows of Outer Hair Cells
- 1 row of Inner Hair Cells
Auditory Nerve and Central Auditory System

Auditory Nerve through the Brainstem to the Auditory Cortex
Auditory Transduction

by Brandon Pletsch
Types of Hearing Loss

Unilateral = one ear
Bilateral = two ears

Conductive = Outer and/or Middle Ear
Sensorineural = Inner Ear/Auditory Nerve
Mixed = Outer and/or Middle and Inner Ear
Auditory Neuropathy Spectrum Disorder and Central Auditory Processing Disorder = Auditory Nerve and Central Auditory System
Permanent Congenital Hearing Loss: CDC HSFS, 2012
Unilateral Hearing Loss – 35%
Permanent Congenital Hearing Loss: CDC HSFS, 2012
Bilateral Hearing Loss – 64%
Permanent Congenital Hearing Loss: CDC HSFS, 2012
Conductive Hearing Loss – 13%
Permanent Congenital Hearing Loss: CDC HSFS, 2012
Sensorineural Hearing Loss – 65%
Permanent Congenital Hearing Loss: CDC HSFS, 2012

Mixed Hearing Loss – 8%
Permanent Congenital Hearing Loss: CDC HSFS, 2012
Auditory Neuropathy Spectrum Disorder – 4%
Prevalence of Hearing Loss

CDC EHDI Survey (2012)

1.6 per thousand – congenital permanent hearing loss

BUT

35% not passing newborn screening are Lost to Follow-up/Lost to Documentation (range 3 – 84%)

ECHO (2002-2013)*

~ 1.0 per thousand - previously unidentified permanent hearing loss

*preliminary data
Causes of Childhood Hearing Loss

- GJB2 mutation, 21%
- Nonsyndromic, 30%
- Other genetic causes, 44%
- Syndromic, 14%
- Other environmental causes, 14%
- Clinically apparent infection, 10%
- Clinically inapparent infection, 11%
- Pendred’s syndrome (SLC26A4), 3%

Incidence at Birth (186 per 100,000)
Causes of Childhood Hearing Loss

- **Incidence at Birth (186 per 100,000)**
  - Pendred’s syndrome (SLC26A4), 3%
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- **CMV**, 21%
Causes of Childhood Hearing Loss

Incidence at Birth (186 per 100,000)

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- Other environmental causes, 14%
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- Clinically inapparent infection, 11%
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- Syndromic, 14%
- Pendred’s syndrome (SLC26A4), 3%
Audiogram – A graph of an individual’s hearing sensitivity, including type and degree of hearing loss

**Frequency** Low Pitch to High Pitch

**Loudness** Soft to Loud

- Quiet Bedroom at Night
- Music
- Lawnmower
- Leaf Blower
- Airplane
Speech Sounds
The Audiogram and Hearing Loss

![Audiogram Graph]

- Normal
- Minimal
- Mild
- Moderate
- Moderate-Severe
- Severe
- Profound
The Audiogram and Hearing Loss

- Normal
- Minimal
- Mild
- Moderate
- Moderate-Severe
- Severe
- Profound

Frequency (Hz)

Intensity (dB HL)
The Audiogram and Hearing Loss
The Audiogram and Hearing Loss

- Normal
- Minimal
- Mild
- Moderate
- Moderate-Severe
- Severe
- Profound
The Audiogram and Hearing Loss

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The Audiogram and Hearing Loss

[Diagram showing different levels of hearing loss: Normal, Minimal, Mild, Moderate, Moderate-Severe, Severe, Profound.]
The Audiogram and Hearing Loss

Normal
Minimal
Mild
Moderate
Moderate-Severe
Severe
Profound
The Audiogram and Hearing Loss

- Normal
- Minimal
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The Audiogram and Hearing Loss

Normal
Minimal
Mild
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Two On-line Resources

Hearing Loss Simulation links

successforkidswithhearingloss.com
Take Home Message

- Hearing loss is described by the parts of the ear affected and can be temporary or permanent.
- An audiogram is how we graph hearing sensitivity and it is very important to develop an understanding of what it means.
- Even mild and moderate hearing loss significantly affects ability to hear speech which affects speech and language development.
Screening and Diagnostics
JCIH Newborn Hearing Screening Guidelines

1-3-6 Model

By 1 month
  Screen hearing

By 3 months:
  Evaluate hearing and complete diagnostic audiology and otolaryngology examinations
  Fit hearing aids if necessary

By 6 months:
  Enroll in Early Intervention Services
Why is it important?
Hearing Tests

• Determine how significant the hearing loss is (mild, moderate, severe, profound)
• Determine the kind (type) of hearing loss (conductive, sensorineural)
• Determine the configuration (is hearing better at some frequencies or pitches or worse in others)
• Used to make decisions on treatment and intervention
Four Main Hearing Tests

• Tympanometry
  • Tympanometry tests how the eardrum and middle ear are working.

• Otoacoustic emissions- OAE
  • OAE tests how the the inner ear or cochlea is working

• Auditory Evoked responses- ABR
  • ABR tests the hearing nerve and auditory pathways of the brain in response to sound.
  • It measures to the quietest level of sound that the child's auditory system can respond to

• Behavioral
  • Using age specific techniques to observe the child’s response to sound
Objective Test

—Requires no behavioral response
—Determine status of auditory system

• Middle ear function
• Inner Ear Function
• Function of central pathways in the brainstem and cortex
Tympanometry

Measured at the plane of the ear drum or Tympanic Membrane

Record how much acoustic energy is transferred into the middle ear

Determine the condition of the middle ear from this measurement
- hole or perforation of the eardrum
- fluid behind the ear drum
- air pressure behind the ear drum
- normal ear drum movement
Equipment for middle ear measurements

• Probe for seal in ear canal
• Speaker to generate tone sound wave
• Microphone to measure reflected sound in the ear canal
• Air pump to deliver positive and negative pressure to the sealed ear canal
• Earphone for other ear for reflex measures
Tympanometry
OAE Overview

- Sound stimulus goes into the ear canal
- *If* the eardrum and middle ear system is healthy AND the Inner Ear is normal
- *Then* a response (echo) from the movement of the outer hair cells can be measured
- Babies are the easiest to test when they are:
  - Younger
  - Quiet or distracted
Auditory Evoked Potentials

- Labeled based on origin of response in system; further “up” the system, the longer the latency
- **ABR**- auditory BRAINSTEM response 10 - 15 msec
- **AMLR**- auditory middle latency 15 - 60 msec
- **ALR**- auditory late response 75 - 200 msec
- **ERP**- Event related potentials 220 - 389 msec
Auditory Evoked Potentials

- ABR- auditory brainstem response occurs in the first 10-15 msec after a sound enters the ear
- “Waves” generated by synchronous nerve firing-volley
  - Waves I and II     VIII nerve
  - Wave III     Superior Olivary Nucleus
                  level of pons
  - Wave IV     Lateral Lemniscus
                pons
  - Wave V     Inferior Colliculus
                level of mid-brain
ABR

• Evaluate nerve conduction delays- timing
• Estimate hearing threshold
  – Electro-physiologic response 10-20 dB above behavioral threshold
ABR Threshold search
from Hearing in Children, Northern and Downs, C7 pp 238 to 257

Figure 7-20. Summed brainstem evoked responses at decreasing intensities. Each response represents 2048 click presentations. (Courtesy of Steven Staller, PhD, Cochlear Corporation.)
# ABR Normal Threshold

Wyoming Valley Healthcare System--Neurophysiology

<table>
<thead>
<tr>
<th>AEP</th>
<th>TIP ABR INTENSITY LEFT.L</th>
<th>14:13:41</th>
</tr>
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<tbody>
<tr>
<td>#2</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Stim:</th>
<th>Avg: Off</th>
<th>Trc 1:</th>
<th>Lat1:</th>
<th>Amp1:</th>
<th>Lat2:</th>
<th>Amp2:</th>
<th>Diff:</th>
<th>Delay:</th>
<th>0 ms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
<td>Off</td>
<td>Click</td>
<td>0.00 ms</td>
<td>0.025 uV</td>
<td>ms</td>
<td>uV</td>
<td>ms</td>
<td>uV</td>
<td>30dB nHL</td>
</tr>
<tr>
<td>Rate: 21.3 Hz</td>
<td>Left: -15dB nHL</td>
<td>Right:</td>
<td>0 ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level dBnHL</th>
<th>Lat ms</th>
<th>Lat ms</th>
<th>Lat ms</th>
<th>Lat ms</th>
<th>Amp uV</th>
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</thead>
<tbody>
<tr>
<td>&gt;70 dB</td>
<td>7.08</td>
<td>0.475</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;50 dB</td>
<td>7.44</td>
<td>0.500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;40 dB</td>
<td>7.84</td>
<td>0.435</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;30 dB</td>
<td>8.36</td>
<td>0.335</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;20 dB</td>
<td>9.00</td>
<td>0.270</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*NORMAL THRESHOLD:*

- 8 ms
- 30dB nHL
- Control no stim
ABR Threshold Mild hearing loss
Why use ABR?

• ABR not affected by patient state or anesthesia- brainstem level response
• Natural sleep or sedation to estimate threshold in infants and children
• Later waves from higher centers response affected by alertness/state
• Sedation or some medications will suppress the middle and late responses
Behavioral Tests

Visual Reinforcement Audiometry (VRA)

Conditioned Play Audiometry (CPA)
Hearing Screening Protocols

- Separate protocols for Well-Baby Nursery and NICU
Newborn Hearing Screening – Well Baby

Physiologic (‘objective’) measure (pass/fail interpretative criteria available; evidence-based; automated):
  – Auditory Brainstem Response (ABR) automated technology
  – Otoacoustic Emissions (OAE) automated technology
  – 2-technology screen: Screen first OAE; if OAE fails receive ABR. If Pass ABR = Pass Screening (NIH 1993)
JCIH 2007

- Limit number of repeated inpatient tests (increases probability of ‘passing’ by chance alone)
- In absence of national calibration standards or uniform performance standard, “audiologists must obtain normative data for the instruments and protocols they use”
- Rescreen of both ears even if only one ear fails initial screening
Hearing Screening Protocols - NICU

- Automated-ABR technology recommended as the primary screening tool for use in the NICU for infants admitted for > 5 days
Re-Screening Protocols - NICU

• NICU infants not passing AABR screening referred immediately to an Audiologist for audiologic rescreening/diagnostic assessment
  – Any ‘rescreening’ must include ABR
  – First diagnostic testing may occur prior to NICU discharge
Audiologic Evaluation

• Should be performed by audiologists experienced in pediatric hearing assessment

• Initial audiologic test battery to confirm hearing loss must include:
  -- Physiologic measures
  -- When developmentally appropriate, behavioral methods
  -- Completed in both ears regardless of the results of screening tests
Audiologic Evaluation – Birth to 6 months (Developmental Age)

- Child and family history
- Frequency-specific AC (air conduction) ABR
- Frequency specific BC (bone conduction) ABR, when indicated
- Click-evoked ABR
  - if infant has risk indicators for neural HL
  - any infant demonstrating no response on FS-ABR requires click-evoked ABR

Some infants with neural HL have no risk indicators

- OAE (DPOAE or TEOAE)
- Tympanometry using 1000-Hz probe tone
- Observation of auditory behavior
  - As cross-check; not for assessment or amplification fitting
Audiologic Evaluation – 6 months to 36 months

• Child and family history

• Parent report of auditory and visual behaviors and communication milestones

• Behavioral audiometry (VRA, CPA), including:
  – Pure-tone audiometry across the frequency range for each ear
  – Speech detection and speech recognition measures

• OAE testing

• Acoustic immittance measures: Tympanometry & Acoustic Reflex Thresholds

• ABR testing if responses to behavioral audiometry are not reliable OR if ABR testing has not been performed previously
Treatment and Intervention

Medical intervention
• surgical treatment
• treatment for chronic middle ear disorder

Hearing aids
Cochlear implants
FM systems
Treatment and Intervention

• Early intervention for overall development
  – Communication modalities
  – Emotional
  – Social
  – Cognitive

• Audiologist work with and refer to
  – Early interventionists
  – Speech-language therapists – specialized in hearing impairment
  – Educators for the deaf or hard of hearing
Spring is my favorite season. The sun shines bright. The flowers begin to grow. I like spring.
Impact of Early Identification
Infants diagnosed with permanent hearing loss should be fitted with amplification within one month of confirmation of HL.
Hearing Aids
Hearing Aids
Cochlear Implant Candidacy Criteria

- Lack of benefit from amplification
- Age: 12 months (FDA, insurance) but sometimes younger
- Degree of hearing loss: bilateral severe to profound
- No medical contraindications
- Education environments and services appropriate for post-CI aural re/habilitation
- Family factors (motivation, expectations)
Cochlear Implant
Early Care & Education Staff

• Important member of the child’s early intervention team
• Questions to ask in order to facilitate maximum inclusion:
  – What can the child hear with and without amplification?
  – What is the optimal communication distance for the child?
  – How can you be trained in trouble shooting the amplification devise?
  – What supportive strategies would help?
Maximize the Auditory Environment

• Ensure amplification system is working
• Audiologist train in device use
• Thoughtful placement to learning centers
• Be aware of and reduce background noise
• Make sure child’s attention is focused on the speaker and talk naturally and clearly
The Listening Bubble

Not in range!  In range & listening!

Out of ‘ear shot’ means language is not caught!
Highlight the Visual Environment

• Position children with HL so they can easily visually focus on activities
• Be sure lighting is appropriate
• Direct to auditory language information
• Ensure child positioning in relationship to the teacher that promotes positive social relationships while enhancing learning
Audiological Monitoring and Managing Hearing Loss

• Hearing can change and get worse
• Plan for future needs - amplification flexibility
• Monitor hearing aid/cochlear implant function – trouble shoot
• Provide educational input and consultation
  - classroom modifications
  - FM
  - educational strategies
Working Collaboratively With Audiologists

1. Make out reach efforts - individual or group
2. Encourage mutual information sharing
3. Invite participation
4. Keep asking questions
Take Home Message

• Children in Early Head Start who refer from screening can and should be assessed as soon as possible to maximize development of maturing auditory skills; sets the stage for language development

• Family choices for treatment and intervention often includes hearing aids/cochlear implants AND early intervention (communication strategies)

• Questions about hearing? Ask your Audiologist!
Hearing Aids

• Hearing aids can be fitted as young as 1 month of age
Take Home Message

• Hearing loss is described by the parts of the ear affected and can be temporary or permanent.

• An audiogram is how we graph hearing sensitivity and it is very important to develop an understanding of what it means.

• Even mild and moderate hearing loss significantly affects ability to hear speech which affects speech and language development.
Hearing Loss Simulation

Profound Hearing Loss

HEARING LOSS SIMULATIONS
http://www.hear2learn.org/CICSsim/index.html
Hearing Loss Simulation

Moderate High Frequency Hearing Loss

HEARING LOSS SIMULATIONS
http://www.hear2learn.org/CICSim/index.html
Hearing Loss Simulation

Mild Mid-Frequency
Hearing Loss

HEARING LOSS SIMULATIONS
http://www.hear2learn.org/CICSsim/index.html
Hearing Loss Simulation

Normal Hearing

HEARING LOSS SIMULATIONS
http://www.hear2learn.org/CICSsim/index.html
The Audiogram and Hearing Loss

- **Normal:** -10 - +15 dB HL
- **Minimal:** 16 - 25 dB HL
- **Mild:** 26 - 40 dB HL
- **Moderate:** 41 - 55 dB HL
- **Moderate-to-Severe:** 56 - 70 dB HL
- **Severe:** 71 - 90 dB HL
- **Profound:** 91 dB HL and greater
### The Audiogram and Hearing Loss

<table>
<thead>
<tr>
<th>Frequency in Hertz (Hz)</th>
<th>Hearing Level in Decibels (dB)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>-10</td>
<td><strong>Normal</strong>: -10 - +15 dB HL</td>
</tr>
<tr>
<td>250</td>
<td>-10</td>
<td><strong>Minimal</strong>: 16 - 25 dB HL</td>
</tr>
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</tr>
<tr>
<td>2000</td>
<td>-10</td>
<td><strong>Moderate-to-Severe</strong>: 56 - 70 dB HL</td>
</tr>
<tr>
<td>4000</td>
<td>-10</td>
<td><strong>Severe</strong>: 71 - 90 dB HL</td>
</tr>
<tr>
<td>8000</td>
<td>-10</td>
<td><strong>Profound</strong>: 91 dB HL and greater</td>
</tr>
</tbody>
</table>

- **Normal**: hearing level within the range of -10 to +15 dB HL
- **Minimal**: likely to detect muffled speech
- **Mild**: may experience mild difficulties in noisy environments
- **Moderate**: may have difficulty understanding conversations
- **Moderate-to-Severe**: may have difficulty understanding conversations in noisy environments
- **Severe**: may have trouble understanding conversations
- **Profound**: unable to hear normal speech
The Audiogram and Hearing Loss

- Normal
- Minimal
- Mild
- Moderate
- Moderate-Severe
- Severe
- Profound
Permanent Congenital Hearing Loss: CDC HSFS, 2011 Laterality Unknown – 2%
Screening in Early Head Start

• The development of brain synapses (brain information connections) are virtually complete after the first three years of a baby's life.
• The first years of life are *the most important* in brain development.
• You have these kids during these years!