Audiology 101: Audiology for non-audiologists working in and supporting EHDI’s activities

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What are “Audiologists”?  

Specialists/experts in **Hearing and Balance**  

We focus on:  

* Prevention of hearing loss  
* Identification and assessment of hearing and balance problems  
* Rehabilitation of persons with hearing and balance disorders
Anatomy and Physiology

Diagram of the ear:
- Pinna
- Malleus (hammer)
- Incus (anvil)
- Stapes (stirrup)
- Cochlea
- Auditory nerve
- External ear canal
- Tympanic membrane (eardrum)

Sound waves enter the ear canal and cause the eardrum to vibrate.

Legend:
- Sound

Diagram labels and annotations explain the components of the ear and their functions in hearing.
Anatomy and Physiology

Divided into 4 parts
* Outer Ear
* Middle Ear
* Inner Ear
* Central Auditory Nervous System
Structures of the Outer Ear

Pinna

- Gathers sound waves
- Aids in localization
- Amplifies sound approx. 5-6 dB
Structures of the Outer Ear

External Auditory Canal or Ear Canal

- Approx. 1 inch long
- “S” shaped
- Outer 1/3 surrounded by cartilage
- Inner 2/3 by mastoid bone
- Isolates TM from physical damage
- Cerumen glands moisten/soften skin
- Presence of some cerumen is normal
Structures of the Outer Ear

Tympanic Membrane or Ear Drum

- Thin membrane
- Forms boundary between outer and middle ear
- Vibrates in response to sound waves
- Changes acoustical energy into mechanical energy
Structures of the Middle Ear

Ossicles

- Ossicular chain = malleus, incus & stapes
- Focus/amplify vibration of TM to smaller area
- Enables vibration of cochlear fluids
- Malleus
  - Attaches to TM
- Incus
  - Connector
- Stapes
  - Smallest bone in the body
  - Footplate inserts in oval window of the cochlea
Structures of the Middle Ear

Eustachian Tube

- Mucous-lined
- Connects middle ear cavity to nasopharynx
- “Equalizes” air pressure in middle ear
- Normally closed, opens under certain conditions
- May allow a pathway for infection
- Children “grow out of” most middle ear problems as this tube lengthens and becomes more vertical
Structures of the Inner Ear

Cochlea
- Snail shaped cavity within mastoid bone
- 2 ½ turns
- 3 fluid-filled chambers
- Contains Organ of Corti
- Converts mechanical energy to electrical energy
Structures of the Inner Ear

Organ Of Corti
- End organ of hearing
- 3 rows of Outer Hair Cells
- 1 row of Inner Hair Cells
- Tectorial and Basilar Membranes
- Cochlear fluids

(From Augustana College, “Virtual Tour of the Ear”)
Structures of the Inner Ear

Hair Cells

* Frequency specific
  * Low pitches = apex of cochlea
  * High pitches = base of cochlea

* Fluid movement causes deflection of nerve endings

* Nerve impulses (electrical energy) are generated and sent to the brain
VIIIth Cranial Nerve or Auditory Nerve

- Bundle of nerve fibers (25-30K)
- Travels from cochlea through internal auditory meatus to skull cavity and brain stem
- Carry signals from cochlea to primary auditory cortex, with continuous processing along the way
Auditory Cortex

- Wernicke’s Area within Temporal Lobe of the brain
- Sounds interpreted based on experience/association
Types of Hearing Loss

- Conductive = Outer and/or Middle Ear
- Sensorineural = Inner Ear
- Mixed = Outer and/or Middle Ear and Inner Ear
- Auditory Neuropathy Spectrum Disorder (AKA Auditory Neuropathy / Dys-synchrony) = Central Auditory System

- Unilateral
- Bilateral
Incidence of Congenital Hearing Loss
CDC EHDI Survey - 2006

* Conductive = 18 %
* Sensorineural = 72 %
* Mixed = 7 %
* Auditory Neuropathy Spectrum Disorder = 3 %

* Unilateral = 22 %
* Bilateral = 73 %
* Laterality Unknown = 5 %
Causes of Sensorineural Hearing Loss

Incidence at Birth (186 per 100,000)

- Clinically apparent infection, 11%
- Pendred’s syndrome (SLC26A4), 3%
- Clinically apparent infection, 10%
- CMV, 21%
- GJB2 mutation, 71%
- Other environmental causes, 14%
- Other genetic causes, 44%
- Syndromic, 14%
- Nonsyndromic, 30%

Newborn Hearing Screening — A Silent Revolution

Cynthia C. Morton, Ph.D., and Walter E. Nance, M.D., Ph.D.
What Does It Sound Like to Have a Hearing Loss?

Severe hearing loss

Moderate hearing loss

Mild hearing loss

Normal hearing
The Audiogram

**Frequency** Low Pitch to High Pitch

**Loudness** Soft to Loud
The Audiogram

- Normal Hearing
- Mild Loss
- Moderate Loss
- Moderate Severe Loss
- Severe Loss
- Profound Loss

Frequency (Hz) Scale: 125, 250, 500, 1000, 2000, 4000, 8000

Intensity (dB) Scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120

Symbols Representing Sound Intensities:
- Quiet Bedroom at Night
- Music
- Lawnmower
- Leaf Blower
- Airplane
Hearing loss is described by the parts of the ear affected and can be temporary, permanent and/or fluctuating.

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

An audiogram is how we graph hearing sensitivity and it is very important to develop an understanding of what it means.
Screening and Diagnostics
JCIH Newborn Hearing Screening Guidelines

• **1-3-6 Model**
  - By 1 month Screen hearing
  - By 3 months Evaluate hearing; complete diagnostic audiology and otolaryngology examinations; fit hearing aids if necessary
  - By 6 months Enroll in Early Intervention Services
Why the rush??

1 month  3 months  6 months  1 year

Laxmi.nuc.ucla.edu
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
Three Main Tests

• Tympanometry-
  - evaluate middle ear pressure
  - status of middle ear system
  - confirm/rule out conductive or temporary hearing loss

• Otoacoustic emissions- OAE
  - echo of Outer Hair Cells from inner ear
  - recorded in ear canal
  - integrity of inner ear

• Auditory Evoked responses- record brain waves in response to sound
  - ABR auditory Brainstem response
  - response from brainstem
Tympanometry

Measured at the plane of the tympanic membrane 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
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  
  – Wave III  
  – Wave IV  
  – Wave V  
  
  VIII nerve  
  Superior Olivary Nucleus level of pons  
  Lateral Lemniscus—pons  
  Inferior Colliculus- level of mid-brain
ABR Pathways

1. Sounds enter the ear
2. Tiny middle ear bones amplify sound
3. Cochlea sorts sounds by frequency
4. Nerve passes signal from cochlea to brain stem
5. Signal travels through brain getting decoded along the way
6. Auditory cortex recognizes, processes sound
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
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
Hearing Screening Protocols

Separate protocols for Well-Baby Nursery and NICU
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; OAE fails receive ABR. Pass ABR = Pass Screening (NIH 1993)
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
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 (Devel. Age)

Child and family history

Frequency-specific AC (air conduction) ABR;

Bone conduction, frequency specific 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
Amplification

Infants diagnosed with permanent hearing loss should be fit with amplification within one month of confirmation of HL.
Treatment and intervention for hearing loss

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 hearing impaired
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 devices, educational strategies)
How to work collaboratively with audiologists

1. Make out reach efforts - individual or group
2. Encourage mutual information sharing
3. Invite participation
4. Keep asking questions
* Infants 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 intervention often includes hearing aids/Cochlear Implants AND early intervention (communication strategies)

* Questions about hearing? Ask your Audiologist