AUDIOLOGICAL EVALUATIONS, FINDINGS AND RECOMMENDATIONS: A PARENT’S GUIDE

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AGENDA

- Anatomy of the Ear
- Types of Audiological Assessment
  - Objective Testing
    - Tympanometry
    - Acoustic Reflexes
    - Otoacoustic Emissions
    - Auditory Brainstem Response
  - Subjective Testing
    - Pure tone assessment
    - Speech audiometry
- Audiogram Interpretation
  - Degree
  - Type
  - Configuration
- Recommendations
ANATOMY OF THE EAR
(the basics)
Objective Assessment
Types of Objective Audiological Assessment

- Tympanometry
- Acoustic Reflexes
- Otoacoustic Emissions (OAE)
- Auditory Brainstem Response (ABR)
TYMPANOMETRY

Plot of:

- Peak Pressure (daPa)
  - How much pressure is required to make the tympanic membrane (ear drum) move?
- Peak Compliance (ml)
  - How much is it able to move?
- Ear canal volume (cc)
  - What is the size of the ear canal?
TYPE A
Type A
TYPE AD

![Graph showing the relationship between air pressure (daPa) and admittance (mmhos). The graph has a vertical axis labeled 'Admittance' with values 0.5 mmhos, 1.0 mmhos, and 1.5 mmhos, and a horizontal axis labeled 'Air Pressure daPa' with values from -400 to 300.]
**Type C**

[Graph showing the relationship between admittance and air pressure in daPa.]
TYPE B TYMPANOGRAMS

- The classification used to describe a non-compliant middle ear system.
- **MUST HAVE A STATEMENT ON EAR CANAL VOLUME**
- 3 kinds:
  - Normal volume
  - Small volume
    - Stenotic canal
    - Impacted cerumen (wax)
    - Foreign body
  - Large volume
    - Patent PE tube
    - TM perforation
"Type B"
Acoustic Reflexes
ACOUSTIC REFLEXES

- Measure the lowest intensity (volume) a sound can be to stimulate the stapedius muscle
  - Called Acoustic Reflex Threshold (ART)
  - Assesses the integrity of the afferent (ascending) and efferent (descending) auditory pathway to the level of the lower brainstem
  - Can be tested:
    - Ipsilateral (probe and sound are in the same ear)
    - Contralateral (probe and sound are in opposite ears)
- Tested at multiple frequencies
- Usually elevated or absent in patients with sensorineural hearing loss

- Measure the integrity of the stapedius muscle in response to a prolonged loud sound (Acoustic Reflex Decay)
ACOUSTIC REFLEXES- TESTING CONSIDERATIONS

- Requires the child to sit very quietly (like a statue) for a prolonged period of time
- May be absent with poor middle ear function
- Usually not assessed if a child has patent PE tubes
- Intensity of the sound may cause a child with hearing loss short, mild discomfort as sounds are loud (recruitment)
- Ambient noise in the room is not a factor
  - Can be assessed as the child watches a video with or without sound
OTOACOUSTIC EMISSIONS
- OAEs are a valid screening and diagnostic tool
  - Widely used as the standard test for the well baby UNHS protocol

- Presence allows the audiologist to comment on the integrity of the OHCs

- **Inability to elicit OAEs may not mean they are truly absent; rather that they could not be measured**
Clinical Significance

- Screening in the well baby nursery and pediatric populations
- Allows audiologist to comment on the function of each cochlea when ear specific information cannot be obtained from behavioral testing (i.e. VRA)
- Usually absent in patients with more than a mild sensorineural hearing loss
WHAT ACTUALLY IS AN OAE?

- It’s literally an echo.
- We are measuring the change that occurs when the hair cells are displaced in the cochlea.
- If the sound loses too much energy the OAE can’t be measured.
OAEs and Noise

- Interfering noise during OAE testing includes both myogenic and extrinsic sources.

- In order to successfully elicit an OAE the stimulus must be sufficiently higher than the noise floor.

- Noise must be limited during testing, especially environmental noise.
 LIMITATIONS OF OAEs

- Cannot be measured if there is poor outer or middle ear function

- Do not estimate auditory thresholds.

- OAEs will be present in the presence of mild sensorineural hearing loss

- Not sensitive to retrocochlear hearing loss
PRESENT DP OAEs
DPOAEs measured in an excessively noisy environment.
AUDITORY BRAINSTEM RESPONSE
AUDITORY EVOKED POTENTIALS

- A classification of objective measures that assesses the integrity of the ascending auditory pathway beyond the level of the cochlea.
- AEP measure time locked changes in the EEG in response to auditory stimuli.
- The latency of these changes correlate to specific areas in the ascending auditory pathways:
  - Early - ABR
  - Middle- Electrocochleography (Ecochg)
  - Late – Cortical Potentials
Clinical Indications of ABR

- Threshold Estimation
- Evaluate neural synchrony
- Sensitive to retrocochlear lesions; especially in those who cannot receive MRI
- Screening tool in the high risk neonate populations
THE MANY NAMES OF “ABR”

- AEP- Auditory Evoked Potential
- BAER- Brainstem Auditory Evoked Response
- BAEP- Brainstem Auditory Evoked Potential
- AABR- Automated Auditory Brainstem Response
- AABAER- Automated Auditory Evoked Response
**Test Environment**

- Myogenic noise must be limited
- Extremely sensitive to electrical interference
  - Nearby medical equipment
  - Elevators
  - Cellphones—especially Androids and iPhones
- Environmental noise can be slightly higher as compared to OAEs
- Helpful if the patient is lying down so they can sleep/relax
**SEDATED OR UNSEDATED...**

**Unsedated**
- Infants up to 4 months can usually be tested unsedated with parental cooperation
- VERY RARELY for children who can be sleep deprived or who routinely take long naps and cannot be sedated

**Sedated/ General Anesthesia**
- Infants older than 4 months
<table>
<thead>
<tr>
<th><strong>Stimuli</strong></th>
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<tbody>
<tr>
<td><strong>Click</strong></td>
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<tr>
<td>- Broadband signal from approx 1000-4000Hz</td>
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<tr>
<td>- More sensitive to retrocochlear lesions and in assessing neural synchrony</td>
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<td>- Used in hearing screening</td>
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<tr>
<td><strong>Tone Burst</strong></td>
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<tr>
<td>- Narrow band of noise that is centered around 1 frequency</td>
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<tr>
<td>- Allows the hearing aid dispenser/audiologist to program hearing aids in populations that cannot volunteer thresholds.</td>
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<tr>
<td>- Used in diagnostic eval</td>
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</table>
- Only **diagnostic** tool to estimate thresholds in patients who cannot or will not perform behavioral audiometry

- Allows the audiologist to obtain frequency specific thresholds that can be used to program hearing aids

- Measuring the lowest level a neural response (called wave V) can be reliably obtained
When is a threshold estimation ABR recommended?

- In a newborn who “referred” UNHS and follow-up screening in the presence of normal middle ear function

- In all newborns with unilateral or bilateral Microtia/Atresia

- In newborns with craniofacial anomalies associated with hearing loss who do not pass UNHS (i.e. cleft lip/palate; Down Syndrome)
Joint Committee on Infant Health (JCIH) 2007

Recommends that all children under 3 who have been diagnosed with a sensorineural hearing loss receive an ABR to confirm behavioral findings
**Recording Parameters (Recommended)**

- Tone burst stimuli at 500, 1000, 2000 and 4000Hz
- Rarefaction or Condensation Polarity
- Rate may vary
- Recording window greater than 10ms.
- Replicate threshold
**Estimated Thresholds**

- Air conduction thresholds may be reported in “dBnHL” or “dBeHL”
- If they are reported in dBnHL air conduction thresholds will need to be converted
- Standard currently used is based off of Stapells (2000) meta-analysis of the differences in behavioral thresholds as compared to ABR thresholds in those with normal hearing
- **There is no conversion factor for bone conduction thresholds.**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Correction Factor</th>
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<tbody>
<tr>
<td>500 Hz</td>
<td>20dB</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>15dB</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>10dB</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>5dB</td>
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**ABR** – Latency/Intensity Function

**Infant ABR**
- Wave I: 1.44 ms
- Wave III: 3.70 ms
- Wave V: 6.29 ms

75 dB nHL: 6.29 ms
55 dB nHL: 6.86 ms
35 dB nHL: 7.58 ms
15 dB nHL: 8.59 ms

**Adult ABR**
- Wave I: 1.70 ms
- Wave III: 3.70 ms
- Wave V: 5.95 ms

75 dB nHL: 5.95 ms
55 dB nHL: 6.33 ms
35 dB nHL: 7.05 ms
15 dB nHL: 8.20 ms

Wave I-III: 2.26 ms
I-III: 2.00 ms

Wave III-V: 2.59 ms
III-V: 2.25 ms

Wave I-V: 4.85 ms
I-V: 4.25 ms
Subjective Audiological Assessment
SUBJECTIVE AUDIOLOGICAL TESTING

- Requires a *behavioral* response from the patient
- Establishes *threshold*
  - The lowest level the patient *reliably* responds 50% of the time
  - 2/4 or 3/6 trials
- Includes:
  - Pure tone audiometry
  - Threshold speech audiometry
TESTING CONSIDERATIONS

- Age
-Intellect
- Comorbid conditions
- Visual acuity
- Dexterity
- Mobility
TRANSDUCERS

- Soundfield
  - Not ear specific
  - Warbled or Narrow Band Noise
  - Cannot test below 15dBHL due to ambient noise
  - Used for functional gain testing
- Headphones
- Inserts
- Bone oscillator
  - Used to condition

\[\text{Determines degree of HL}\]
\[\text{Determines Type of HL}\]
STIMULI

CSTIMULI

Frequency Specific

Types:
- Pure tones
- Warble tones
  - Modulated pure tone
- Narrow band noise
  - Sound that is narrowly filtered around centered frequency

General test order:
- 2000Hz, 500Hz, 4000Hz, 1000Hz, 6000Hz, 8000Hz, 250Hz

Speech

Threshold Estimation
- Speech Awareness Threshold (SAT)
- Speech Recognition Threshold (SRT)

Speech discrimination
- Phonemes
- Words
- Sentences
**SAT vs SRT**

**SAT**
- Lowest level a patient can **detect** speech
- Usually 10-15dBHL lower than best frequency response
- Phoneme or name
- Phrase (put it in)

**SRT**
- Lowest level a patient can **identify** a familiarized wordlist (closed-set)
- Usually the words are spondees (2 syllable words with equal emphasis)
- Can be a Body ID
- Response can be:
  - Oral
  - Pointing
Speech Discrimination Score (SDS)/Ability/Word Recognition Score (WRS)

- Ability measured in % to repeat or point to unfamiliarized speech presented at a suprathreshold level (40dBSL re:SRT)
- Open or closed set (WIPI)
- Often used to assess potential or actual benefit from hearing aids, cochlear implants, bone conduction/anchored hearing aids
- Can be assessed in the presence of competing background noise
- Many different word lists- must select language age appropriate
# Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Acronym</th>
<th>Age*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavioral Observation Audiometry</td>
<td>BOA</td>
<td>&lt;9 m</td>
</tr>
<tr>
<td>Visual Reinforced Audiometry</td>
<td>VRA</td>
<td>9 m-3 yrs</td>
</tr>
<tr>
<td>Conditioned Play Audiometry</td>
<td>CPA</td>
<td>3-5 yrs</td>
</tr>
<tr>
<td>Conventional Audiometry</td>
<td></td>
<td>5+ years</td>
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***In the Typically Developing Child***

- Gold Standard- 2 audiologist testing
- Technique is often adjusted based on the abilities of the child
Behavioral Observation Audiometry

- Consistent, repeatable, reliable response that is identified at an intensity that is suprathreshold
- The response MUST be agreed upon by 2 clinicians
  - MUST TEST WITH TWO AUDIOLOGISTS
- Can be:
  - Cry
  - Smile
  - Sucking
  - Cessation of sucking
  - Eye shift
**VISUAL REINFORCED AUDIOMETRY**

- **Conditioned response**
  - Present a stimulus and simultaneous “reward” (video screen) at a suprathreshold level and teach the child to turn in response to the sound and repeat 3-5 times
  - May have to be done several times during a test session

- **After the child is conditioned you lower the intensity and establish threshold**
CONDITIONED PLAY AUDIOMETRY

Conditioned response
- “Testing” Audiologist presents a suprathreshold stimulus as the “assisting” Audiologist demonstrates hand-over-hand desired response (repeated 3-5 times)
- Responses:
  - Dropping a toy in a bucket
  - Building blocks or cups
  - Peg board
  - Dressing a doll/ Mr. Potato Head
  - Dancing/Shaking in the chair
  - Poking the child’s nose
  - Clapping
  - (the longer we test the more creative we get)
- After the child is conditioned you lower the intensity and establish threshold
PUTTING IT ALL TOGETHER
<table>
<thead>
<tr>
<th>Age</th>
<th>Transducer</th>
<th>Speech Audiometry</th>
<th>Pure tone Audiometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOA</td>
<td>Soundfield</td>
<td>SAT</td>
<td>Warbled tones</td>
</tr>
<tr>
<td></td>
<td>Bone Oscillator</td>
<td></td>
<td>Narrow Band Noise</td>
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<tr>
<td>&lt;9 m</td>
<td></td>
<td></td>
<td>Warbled tones</td>
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<td></td>
<td></td>
<td>Pure tones</td>
</tr>
<tr>
<td>VRA</td>
<td>Soundfield</td>
<td>SAT</td>
<td>Warbled tones</td>
</tr>
<tr>
<td>9m - 3 yrs</td>
<td>Inserts</td>
<td>SDS</td>
<td>Narrow Band Noise</td>
</tr>
<tr>
<td></td>
<td>Bone Oscillator</td>
<td></td>
<td>Warbled tones</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Narrow Band Noise</td>
</tr>
<tr>
<td>CPA</td>
<td>Soundfield</td>
<td>SAT</td>
<td>Warbled tones</td>
</tr>
<tr>
<td>3 - 5yrs</td>
<td>Inserts Headphones</td>
<td>SRT SDS</td>
<td>Narrow Band Noise</td>
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<td></td>
<td></td>
<td></td>
<td>Warbled tones</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Pure tones</td>
</tr>
</tbody>
</table>
Audiogram Interpretation
ABBREVIATIONS

- AD - Right Ear
- AS - Left Ear
- AU - Both Ears
- CHL - Conductive Hearing Loss
- SNHL - Sensorineural Hearing Loss
- MHL - Mixed hearing loss
- SAT - Speech Awareness Threshold
- SRT - Speech Recognition Threshold
- SDS - Speech Discrimination Score
- AC - Air Conduction
- BC - Bone Conduction
- NR - No Response
- HA - Hearing Aid
- S - Soundfield
- CI - Cochlear implant
- OAI - Osseointegrated Auditory Implant
- BAHA - Bone Anchored Hearing Aid
- BCHA - Bone Conduction Hearing Aid
- ENT - Ear, Nose Throat (surgeon)
- AUD - Audiology/Audiologist
AUDIOPHGRAM

Visual representation of pure tone audiometry

- Represents:
  - Degree
  - Type
  - Configuration
Audiogram of Familiar Sounds

Normal Hearing

Conversational Speech

Intensity

Soft

Loud

Low

Frequency (Pitch)

High
DEGREES OF HEARING LOSS

NORMAL
SLIGHT
MILD
MODERATE
MODERATELY-SEVERE
SEVERE
PROFOUND
SYMBOLS

There should ALWAYS be a legend on an audiogram

Symbols are UNIVERSAL

Color Coating
  - Right ear= RED
  - Left Ear= BLUE

Bone Conduction (BC) symbols reference patient right and left.

<table>
<thead>
<tr>
<th></th>
<th>Unmasked</th>
<th>Masked</th>
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</thead>
<tbody>
<tr>
<td>RIGHT</td>
<td>AC</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>BC</td>
<td>&lt;</td>
</tr>
<tr>
<td>LEFT</td>
<td>AC</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>BC</td>
<td>&gt;</td>
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</table>

No Response (NR) designated by a downwards arrow

Soundfield = S
TYPES OF HEARING LOSS

- Conductive (CHL)
  - Air conduction (AC) responses are not within normal limits (WNL)
  - Bone Conduction (BC) responses are WNL
  - AC-BC ≥ 15dBHL (called an air-bone gap~ABG)

- Sensorineural (SNHL)
  - AC and BC are impaired
  - AC-BC ≤ 10dBHL

- Mixed (MHL)
  - AC and BC are impaired
  - ABG ≥ 15dBHL
CONDUCTIVE HEARING LOSS (CHL)
SENSORINEURAL HEARING LOSS (SNHL)
Mixed hearing loss (MHL)
Recommendations
MANDATORY INITIAL RECOMMENDATIONS

- All ages:
  - Evaluation by ENT
    - Should be Pediatric and/or Otology
      - ENT may order:
        - Genetic evaluation
        - Imaging
          - MRI
          - CT
  - Audiological re-evaluation at least every 6 months
  - Evaluation by Ophthalmology
  - Most states child will be added to the hearing loss registry
ADDITIONALLY FOR CHILDREN AGES:

Birth to 3 years:
- ABR to confirm behavioral findings
- Referral to Early Intervention (EI):
  - Speech-language
  - Teacher of the Deaf and Hard of Hearing (TODHH)
  - Physical Therapy Evaluation
  - Occupational Therapy Evaluation
  - Developmental Evaluation

3-5 years:
- Referral to the Committee for Preschool Special Education (CPSE):
  - Speech-language
  - Teacher of the Deaf and Hard of Hearing (TODHH)
  - Physical Therapy Evaluation
  - Occupational Therapy Evaluation
  - Developmental Evaluation
AMPLIFICATION RECOMMENDATIONS

- Always binaural if hearing loss is symmetrical and in both ears
- Pediatric Hearing Aid
- Pediatric fitting rationale
  - Due to the difference in the size of the child’s ear canal
- Verify that they are not over/under amplifying via functional gain and Real Ear Assessment
- Tamper resistant battery doors
- Larger earmolds
  - Choking hazard
  - Better fit
- Use a retention cord to prevent loss
- FM Compatible
RECOMMENDATIONS FOR THE SCHOOL-AGE CHILD
IMPROVE THE SIGNAL-TO-NOISE RATIO!

- Most recommendations for the school-age child refer to improving the child’s **signal-to-noise ratio (SNR)**
  - The SNR is the difference between how loud the signal (speaker) and the noise in the room
    - +SNR means the speech is __dB louder than the noise
    - -SNR means the speech is __dB softer than the noise
  - A child with normal hearing requires a minimum of a SNR of +6dB to effectively learn (Crandell, 1991)
  - A child with a slight to mild hearing loss performs 13% poorer than a child with normal hearing with a SNR of +6dB (Crandell, 1993)
  - At a SNR of -6dB, a child with a slight to mild hearing loss will perform 33% poorer than the normally hearing child
When is the SNR worst in a classroom?

- During transition times
  - Books closing
  - Desks moving
  - Kids talking
WHAT IS THE CHILD WITH HEARING LOSS MISSING?

- Instructions on the next task
- Assignments
- “Oh by the way read pages 210-245 there will be a quiz on Wednesday”
HOW DO WE FIX THIS?

- Written instructions – **have it added to your child’s IEP**
- Use of a note taker
  - When the child reaches the age where lectures are more common
  - Can be remote- CART system
  - Another classmate who does not know for whom they are taking notes
- “Preferential Classroom Seating”
- Use of an FM system
“PREFERENTIAL CLASSROOM SEATING”

- Only helpful if the teacher stands directly in front of the child and never faces the black/white/smart board.
- Recommendations for preferential classroom seating should be specific:
  - Which ear should be closer to the teacher
  - Separate from external windows and doors
  - No further than 3 feet from the student at all times
  - Must maintain eye contact
- Very unrealistic (but I still recommend it)
FM SYSTEM

- An assistive device that places the voice of the speaker closer to the listener

- 2 parts:
  - Transmitter - teacher worn
  - Receiver – student worn

- Can be delivered in a variety of ways:
  - To all students in a room
    - Cost effective in classrooms with multiple hearing impaired students
  - At desk level
    - Called a sound box/bag
  - At ear level
    - Through headphones/ear buds
    - In-the-ear receivers
    - Directly though hearing aids/cochlear implants
RECOMMENDATIONS FOR FM SYSTEM

- The audiologist should make specific recommendations (i.e. ear level with dedicated receivers)
- Need to be programmed by an Educational Audiologist
  - Especially important if there are multiple children in the school using FM systems as there can be interference
- Should be maintained by the school
  - Includes charging!!!
- Every teacher should use it
  - Exception: Gym as if the receiver falls out it can break
FM Log

- As your child starts to change classes it will need to be moved from class to class
- Ask that a log be included in the bag for the FM that requires each teacher to sign for it daily
  - Helpful if it breaks
  - Ensures that each teacher is using it
  - Ask for a copy of the log to be sent home at particular intervals
A FINAL WORD...
You know your child better than anyone- don’t be afraid to ask the “professional” to explain their rationale for their recommendation

Give suggestions and ask if they would be appropriate

A rationale for a recommendation should be based on research and data (called evidence based practice)
REFERENCES

QUESTIONS?