Hearing Aid Fitting in Children: Audibility Matters

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Objectives

- Objectives of Early Amplification
- Importance of Verification
- Introduction to the Outcomes of Children with Hearing Loss (OCHL)
  - Large, multi-center study of hard of hearing children in US
  - Brief discussion of characteristics of hearing aid fitting on enrolled children
Acknowledgements

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BTNRMH

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BTNRMH

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University of Iowa
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- US National Institutes of Health
  - R01 DC009560
  - R01 DC013591
Acknowledgements: “Mr. DSL”
Sao Paulo 2007
Soracaba 2007
Universal NB screening legislation 1999
Pediatric Audiology and CI Teams
CASTLE pre-school
Total 1400 infants and children
  » 900 using amplification
  » 800 with cochlear implants
  » 200+ with ANSD diagnosis
Where is North Carolina?
Audiologic Management of Infants and Young Children: Essential Components

- **Diagnostic Evaluation**
  - Auditory Brainstem Response (ABR)
  - Acoustic Immittance
  - Otoacoustic Emissions

- **Hearing Aid Selection and Fitting**
  - Appropriate selection of device (size, features)
  - Hearing aid programming
  - Hearing aid verification
  - Hearing aid validation

- **Behavioral Audiometry**
  - Visual reinforcement audiometry (VRA)
  - Conditioned play audiometry (CPA)
Estimate Audiogram Using ABR
Hearing Instrument Selection and Ear Impressions

- If family ready to proceed, ear impressions taken
- Hearing instruments selected
- Return appt for hearing instrument fitting two weeks later
- Ideally between 2-3 months of age
Hearing Aid Fitting Using Evidence Based Protocols

- AAA Pediatric Amplification Protocol 2013
- Ontario Protocol for the Provision of Amplification 2014
Referral for Early Intervention

- Referral to “Beginnings” on day hearing loss diagnosed (www.ncbegin.org)
- Family contacted within one week of diagnosis and home visit from early childhood specialist scheduled
  - Written materials and video provided to family
- Weekly home visits with teacher of the deaf/speech and language pathologist scheduled
Behavioral Audiologic Assessment

- Begin VRA at 6-7 months

- Goal: Complete audiogram for each ear (air and bone) by 8-9 months of age.

- Hearing aids readjusted as new threshold information is obtained ***
Timeline
Early Diagnostic Evaluation & Management of Hearing Loss

- Diagnostic ABR
- ASSR, OAE
- History & Physical
- Medical Evaluation
- EKG
- Imaging
- Genetic Testing
- Early intervention Services
- Auditory-based Therapy
- Initiation of HA Trial

- Behavioral audiometric Testing
- Confirmation of Thresholds
- Auditory-based Therapy
- Consider CI Evaluation
- Evaluation of HA Trial

- Cochlear Implantation/HA?
- Auditory-based Therapy

- Newborn infant hearing screening
- Birth
- 0 Day 1-7
- 2-4 Months
- 6-9 Months
- 11-14 Months
- Time
Protocol for the provision of amplification
Ontario Infant Hearing Program

Objectives of Early Amplification

• Provide amplified speech signal that is consistently audible across varying input levels
• Avoid distortion of varying inputs at prescribed settings
• Ensure amplification of sounds in as broad a frequency range as possible
• Include sufficient electro-acoustic flexibility to allow for changes in required frequency/output characteristics related to ear growth or changes in the auditory characteristics of the infant

Bagatto, Scollie, Hyde and Seewald
- International Journal of Audiology 2010
How Do We Ensure that Speech is Audible for Infants and Young Children?

- **Accurate determination of thresholds** at time of diagnostic hearing evaluation using frequency specific ABR
- **Program hearing aids** using manufacturer’s software as a starting point
- **Verify** that hearing aid settings are appropriately matching prescriptive targets for gain and output across frequency range after measuring the RECD
- **Follow** established pediatric amplification protocols
  - AAA Pediatric Amplification Protocol 2013
  - Ontario Protocol for the Provision of Amplification 2014
Verification Methods

- Functional gain/aided soundfield (not recommended)
- Real ear measures with probe mic
- Simulated real ear measures in test box—measured RECD
- Simulated real ear measures in test box—average RECD
Verification Methods

- Functional gain/aided soundfield (not recommended)
- Real ear measures with probe mic
- Simulated real ear measures in test box—measured RECD
- Simulated real ear measures in test box—average RECD
We wouldn’t consider fitting hearing aids like this...
Why Would We Consider Verifying Hearing Aids Like this…

Audiogram with hearing aids is NOT verification

- No information about speech audibility.
- Cannot assess maximum output.
- Represents a stimulus and level that are not encountered by children e.g. warbled tones.
- No estimation of advanced features

ONLY appropriate for validation of CIs and bone conduction devices or as a demonstration to families!
Verification Methods

- Functional gain/aided soundfield (not recommended)
- Real ear measures with probe mic
- Simulated real ear measures in test box—measured RECD
- Simulated real ear measures in test box—average RECD
Real Ear Measures Optimal But…

• Accurate method for determining if prescriptive targets met but…

• Requires child or adult to sit quietly while programming and verifying match to targets
Most Toddlers Aren’t So Patient...
Verification Methods

- Functional gain/aided soundfield (not recommended)
- Real ear measures with probe mic
- Simulated real ear measures in test box—measured RECD
- Simulated real ear measures in test box—average RECD
Measuring the RECD

- Measure signal of known intensity in a 2 cc coupler
- Measure the *real ear SPL* for the same signal with insert earphone or child’s earmold
- $\text{RECD} = \text{real ear SPL} - \text{coupler SPL}$
RECD Measurement
RECDs for Infants and Toddlers

Slide Courtesy of Richard Seewald
Measured RECDs are best but there are times when measurement just not possible…
Verification Methods

• Functional gain/aided soundfield (not recommended)
• Real ear measures with probe mic
• Simulated real ear measures in test box—measured RECD

• Simulated real ear measures in test box—average RECD
Predicted (Average) RECD values

Real-Ear-to-Coupler Difference (RECD) Predictions as a Function of Age for Two Coupling Procedures

Marlene Bagatto, Susan Scollie, Richard Seewald, K. Shane Moodie, & Brenda Hoover
2002, JAAA, vol 13(8)
Predicted RECD Values: Earmolds

![Graphs showing RECD values for different frequencies (500 Hz, 1000 Hz, 2000 Hz, 4000 Hz) against age in months.](image)
Predicted RECD Values

Limitations:
  » High variability in RECD measures associated with children of the same age

Therefore, whenever possible, predicted values should NOT replace a more precise RECD measurement.
Speech Mapping

Speechmap/DSL 5.0a child

Instrument: BTE
Mode: Test box
Presentation: Single view
Format: Graph
Scale (dB): SPL

Audiometry
Age: 15 months
Transducer: Insert+Foam
UCL: Average
RECD: Average
BCT: Ni/A
Binaural: No

<table>
<thead>
<tr>
<th>Test</th>
<th>Stimulus</th>
<th>Level</th>
<th>SII</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td></td>
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</table>

Unaided avg (65) 13

Child’s thresholds

Average speech (Unaided)

Normal Hearing Levels
Match targets for Gain and Output

Connect coupler and instrument to coupler microphone. Select one of REAR 1 through REAR 4.
Goal: Audible Speech Signal for Average Speech Inputs...

Connect coupler and instrument to coupler microphone. Select one of REAR 1 through REAR 4.
…Soft Speech (55dB input level)
And... Loud Speech (75dB input level)

Connect coupler and instrument to coupler microphone. Select one of REAR 1 through REAR 4.
Audibility and Comfort With Varying Speech Input Levels

Connect coupler and instrument to coupler microphone. Select one of REAR 1 through REAR 4.
Goal: Maximum Output that Does Not Exceed Comfort Levels
Another way to quantify audibility is through the Speech Intelligibility Index (SII).

Some frequencies contribute more than others to the intelligibility of speech.

Above line = dots inaudible; below line = dots audible

More dots = more important

Less dots = less important
Quantifying audibility: Speech Intelligibility Index

Each dot = ~1% of the information contributing to speech clarity.

Number of dots that are audible predict how well one understands quiet speech from a six foot distance.

Dots unevenly distributed - more between 1000 and 3000 Hz than 250 to 500 Hz.

Why?

Consonants (high frequencies) contribute more to intelligibility of speech.

Speech intelligibility index (SII)

For each band:
Audibility x FIW = weighted audibility

\[ \text{SII} = \text{Sum of weighted audibility of all frequency bands} \]

Aided SII
Unaided SII
What Happens When We Don’t Verify?

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<th>Stimulus</th>
<th>Level</th>
<th>SII</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Speech-std(1)</td>
<td>Avg (70)</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>MPO</td>
<td>90</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td></td>
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<td>4</td>
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Unaided avg (65) | 0

Audiometry:
- **Age**: 23 months
- **Transducer**: Insert+Foam
- **UCL**: Average
- **RECD**: Average
- **BCT**: N/A
- **Binaural**: No

Instrument: BTE
Mode: Test box
Presentation: Single view
Format: Graph
Scale (dB): SPL
Best Match to Targets…but SII only 46
Consider Other Strategies?
DOES ALL OF THIS WORK??
Outcomes of Children with Hearing Loss

A study of children ages birth to six (2008-2013)

Principle Investigators:
Mary Pat Moeller, PhD
Bruce Tomblin, PhD

A study funded by the National Institutes of Health – National Institute on Deafness and Other Communication Disorders (NIH-NIDCD)
Grant # DC009560
Introduction to OCHL

- Participating sites:
  - University of Iowa
  - Boys Town National Research Hospital
  - University of North Carolina—Chapel Hill

- Target population:
  - Epidemiologic sample of children with HL
    - Ages 6 months to 6 years 11 months
    - English spoken in the home
    - No major secondary disabilities
    - Permanent Mild to Severe Hearing Loss
      - PTA of 25-75 dB HL (.5, 1, 2, 4 kHz)
  - Cohort of age-matched, normal hearing children
Domains of study

- Speech Production
- Language Skills
- Academic Abilities
- Psychosocial and Behavioral
- Hearing & Speech Perception
- Background characteristics of child/family
- Interventions (clinical, educational, audiological)

Child and Family Outcomes
Accelerated Longitudinal Design

- Retrospective data prior to enrollment obtained through medical records
- Cross-sectional and longitudinal
Who are the OCHL participants?

<table>
<thead>
<tr>
<th>SUBJECTS</th>
<th>TOTAL</th>
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<tbody>
<tr>
<td>HH</td>
<td>316</td>
</tr>
<tr>
<td>NH</td>
<td>115</td>
</tr>
</tbody>
</table>
Audiograms from visit 1-4

First visit

Fourth visit
# HH-NH Matched sample

<table>
<thead>
<tr>
<th></th>
<th>HH</th>
<th>NH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects</td>
<td>316</td>
<td>115</td>
</tr>
<tr>
<td>Hearing (PTA)</td>
<td>25-75 dB HL</td>
<td>&lt; 20 dB HL</td>
</tr>
<tr>
<td>Age ranges</td>
<td>0;6 to 6;11 at entry</td>
<td></td>
</tr>
<tr>
<td>Nonverbal IQ</td>
<td>Within the average range</td>
<td></td>
</tr>
<tr>
<td>Maternal education</td>
<td>Matched but &gt; US sample</td>
<td></td>
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<tr>
<td>Language use</td>
<td>Spoken English in the home</td>
<td></td>
</tr>
<tr>
<td>Additional disabilities</td>
<td>No autism; no major vision, cognitive, or motor disabilities</td>
<td></td>
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</tbody>
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How does OCHL differ from other studies?

- No additional disabilities
  - Other studies of children with disability showed much variability
- Only children who wear hearing aids
  - Auditory experience for children with Cis less variable
  - Children with hearing aid understudied
- Amplification data collected at each study visit
- Mix of standardized measures and experimental measures
Amplification data

- Hearing aid verification and hearing aid use data collected at each study visit
- Other studies have assumed
  - Good audibility
  - Consistent hearing aid use
- Allowed analysis of the specific effects of amplification on development
Characteristics of Hearing Aid Fittings in Infants and Young Children

Ryan McCreery, Ruth Bentler, Patricia Roush
Ear and Hearing 2013 Nov-Dec;34(6):701-10
Characteristics of Hearing Aid Fittings in Infants and Young Children

Data from 195 children participating in OCHL study analyzed

• Proximity of the hearing aid fitting to the intended prescriptive targets quantifies by:
  » Calculating the average root-mean-square (RMS) error of the fitting compared to the DSL prescriptive target for 500, 1000, 2000 and 4000Hz

• Aided audibility was quantified by using the Speech Intelligibility Index (SII)
Characteristics of Hearing Aid Fittings in Infants and Young Children

- Survey data from the pediatric audiologists who fit the amplification for children in the study were collected to:
  - Evaluate fitting practices and relate those patterns to proximity of the fitting to prescriptive targets and aided audibility
Results

• More than ½ (55%) of children had at least one ear that deviated from prescriptive targets by more than 5 dB RMS on average
  • Deviation from prescriptive target was not predicted by PTA, assessment method or reliability of assessment.

• Study location was a significant predictor of proximity to prescriptive target with locations that recruited participants who were fit at multiple locations having larger deviations from target than the location where participants were recruited from a single, large pediatric audiology clinic
Results

- Approximately 26% of children had aided audibility less than 0.65 on the Speech Intelligibility Index (SII).
- Fittings based on average RECDs resulted in larger deviations from prescriptive targets than fittings based on individually measured RECDs.
- Aided audibility was significantly predicted by proximity to prescriptive targets and pure tone average.
Actual Hearing aid fit quality

McCreery, Bentler, Roush, 2013
Optimal fitting of hearing aid (< 5dB RMS error)

Filled symbols = rms error < 5 dB

Range of expected values for SII relative to PTA (Bagatto et al., 2011)

Take home message:
Hearing aids are not appropriately fit for all children

$n = 195$

McCreery, Bentler, Roush, 2013
Accuracy of Verification methods

Probe microphone real ear measures
RMS error= 5.67 dB (SD = 3.95 dB)

Functional gain (aided soundfield)
RMS error=7.92 dB (SD = 4.67 dB)

McCreery, Bentler, Roush, 2013
Conclusions

• Quality of hearing aid fitting is dependent on accurate threshold information
  » Accurate estimated thresholds from ABR or ASSR or
  » Accurate thresholds from behavioral audiometry

• Ear canal acoustics must be accounted for in HAF

• Verification of hearing instrument fitting with real ear or simulated measures provide best audibility
  » Best method is either actual real ear measures or
  » Measured RECDs and simulated real ear measures
Conclusions

• Unaided and Aided Speech Intelligibility Index (SII) can also be useful in determining adequacy of hearing aid fitting

• Results from large multi-center study in US indicates that while many children have hearing aids that are fit appropriately and show good audibility; some are still not receiving adequate audibility in order to achieve optimal outcomes
References and Resources

Obrigado!

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