The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening

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The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening

- Learner Objectives:
  1. List three limitations of pure tone hearing screening in young (birth to 3 years) preschool children
  2. Cite three factors contributing to loss-to-follow up of infants who yield a ”refer” screening outcome
  3. Describe three specific advantages of OAEs in preschool hearing screening
The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening

- Introduction to Early Hearing Detection and Intervention (EHDI): 0-10 minutes
- Guidelines for preschool hearing screening and limitations of pure tone screening: 11-30 minutes
- Summary of research in support of OAEs in preschool hearing screening: 31-45 minutes
- Evidence-based strategy for applying OAEs in preschool hearing screening: 46-55 minutes
- Summary, questions & answers: 56-60 minutes
Early Hearing Loss Detection and Intervention:  
*The Ideal 1-3-6 Approach to EHDI*

- < 1 month
  - An infant is identified with hearing loss through hearing screening
- < 3 months
  - Hearing loss is diagnosed following JCIH guidelines
- < 6 months
  - Appropriate intervention is implemented based on diagnostic findings.
Early Hearing Loss Detection and Intervention (EHDI): The Problem of “Loss to Follow Up”

- Most (90 - 98%) newborn infants undergo hearing screening
- > 40% of the children who fail hearing screened do not undergo timely diagnostic evaluation
- Intervention can’t begin without diagnosis
- Multiple and diverse reasons for infants “lost to follow-up”
  - Newborn infants discharged from nursery before screening
  - Infants transferred to another hospital before screening
  - Infants screened in one state and living in another state
  - Failure to document screening or diagnostic findings
  - Family reasons, e.g.,
    - Transportation problems
    - Misunderstanding about need for follow-up
    - Infant has no primary care physician (medically homeless)
Early Hearing Loss Detection and Intervention (EHDI): The Problem of Infants “Lost to Follow Up (LFU)”

- Well-organized systems for data management and tracking

- Education of
  - Hospital personnel
  - Primary care physicians and pediatricians

- Combination OAE/AABR hearing screening approach for lower failure rate and early diagnosis of hearing loss

- Diagnostic assessment immediately following screening failures in hospitals with audiology clinical services

- More qualified audiologists widely distributed throughout each state to provide diagnostic evaluations

- Tele-audiology strategies for diagnostic evaluations

- Pre-school hearing screenings
Early Hearing Loss Detection and Intervention (EHDI): *Pre-School Hearing Screening is a Logical Extension of EHDI*

- Sites or venues for pre-school hearing screening
  - Primary care physician’s office
    - Well baby visits
    - Immunizations
    - Concerns about ear infections or hearing
    - Physician visits for non ear-related reasons
  - Head Start Programs
  - Pre-school educational programs
  - Day care facilities
Early Hearing Loss Detection and Intervention (EHDI): 
*Rationale for Pre-School Hearing Screening*

- Permits identification of hearing loss in children who were not screened as newborns
- Up to 50% of children undergoing newborn hearing screening are “lost to follow-up (LFU)”
- Identifies children with delayed onset or progressive hearing loss
- Approximately 15% of children with hearing loss passed infant hearing screening
- Otitis media and other middle ear disorders are common in the pre-school population
Year 2007 Joint Committee on Infant Hearing (JCIH):
Risk Indicators for Delayed Onset or Progressive Hearing Loss

Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs
Joint Committee on Infant Hearing
Pediatrics 2007;120;898
DOI: 10.1542/peds.2007-2333
Year 2007 JCIH Position Statement: Risk Indicators Associated with Permanent Congenital, Delayed-Onset, or Progressive Hearing Loss in Childhood

- Delayed onset, late onset, or “acquired” hearing loss: Normal auditory function (hearing) at birth with the onset of auditory dysfunction (hearing loss) in infancy or early childhood
- Progressive hearing loss: Normal auditory function (hearing) at birth with the onset of auditory dysfunction (hearing loss) in infancy or early childhood
Increased Prevalence of Hearing Loss in School Age Children versus Newborn Infants

- Fortnum et al. (2001). *BMJ*, 323, 536-554
  - Prevalence within 17,160 children increased from 1% at age 3 years to 2% at age 9 to 16 years
  - Up to 50% of children with hearing loss at age 9 passed newborn hearing screening.

  - UNHS programs do not detect 10 to 20% of permanent hearing loss that begins later

- White (October 2010). ASHA Virtual Audiology Conference
  - Prevalence of 3/1000 for permanent hearing loss in infants increases to 9-10/1000 in school age children
The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening

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- Guidelines for preschool hearing screening and limitations of pure tone screening
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- Evidence-based strategy for applying OAEs in preschool hearing screening
- Summary, questions & answers:
Guidelines for Preschool Hearing Screening and Limitations of Pure Tone Screening

- 1982 US Department of Health and Human Services, PHS
- 1984 American Academy of Pediatrics Policy Statement
- 1985 ASHA Guidelines for identification audiometry
- 1989 US Preventive Services Task Force
- 1989 American Public Health Association
- 1990 ASHA Guidelines for Screening of Hearing Impairment and Middle-Ear Disorders
- 1997 ASHA Guidelines for Audiologic Screening
- Current clinical guidelines will be discussed in a minute
Guidelines for Preschool Hearing Screening and Limitations of Pure Tone Screening

- ASHA Guidelines for Audiologic Screening (1997): Hearing screening of 7-month old through 2-year old children
  - “The panel concluded that for this age group, the development of screening guidelines to be used only by audiologists was appropriate and necessary.”
  - For children who can be conditioned for play audiometry use earphones and screen at 20 dB HL for 1000, 2000, and 4000 Hz
  - For children who can be conditioned for VRA use earphones and screen at 30 dB HL for 1000, 2000, and 4000 Hz
  - Alternatives include screening in calibrated sound field for those children who do not accept earphones
Pre-School Pure Tone Hearing Screening

Questions to Ask About Research Studies

- Qualifications of persons performing hearing screening, e.g.,
  - Audiologist
  - Graduate student in audiology or speech pathology
  - Other health professional
  - Trained non-health professional
- Ambient noise levels in the test environment
- Screening protocol including
  - Earphone type (supra-aural versus insert)
  - Test frequencies
  - Response criteria
- How many children could not be tested (CNT)?
- What were the PASS and FAIL (did not pass) rates?
Behavioral Pre-School Hearing Screening: 
*Not Feasible for Young Preschool Children*


**Methods**
- 100 preschool children age 36 to 60 months
- Testing unsuccessful for additional 3 children
- Screening performed by audiology PhD student
- Settings were daycare centers ... “moderate to high socioeconomic status”
- Hand raising response
- Protocol and ambient noise consistent with ASHA guidelines
Pure Tone Hearing Screening Failure Rate
*(Krishnamurti, Hawks & Gerling, 1999)*

Figure 3. Percentage of screening failures by younger (36 to 48 months) and older (> 48 months) subjects for all tests (pure tone, spondee, and FM tone), pure tone (PTs), spondee and FM tone (Sp\FM), and 2 or 4 kHz pure tones.

Initial pure tone screening failure rate = 24%
Pure Tone Hearing Screening Test Time
(Krishnamurti, Hawks & Gerling, 1999)

Note: Not conditioned play audiometry
Behavioral Pre-School Hearing Screening in Public Pre-School, Day Care or Head Start Settings

  - 34,979 preschool children age 3 to 5 years
  - Settings were public pre-school, day care, or head start centers
  - Pure tone screening at 20 dB for 1000, 2000, 3000 & 4000 Hz
  - Audiology or SLP graduate students from 6 different academic programs in NYC and Long Island area performed screening
  - Hand raising response with CPA if CNT
  - “Difficult to test” children were screened by supervisor
  - Immediate rescreen of failures by supervising audiologist
  - Tympanometry after pure tone screening by supervisor
Evidence-Based Problems with Behavioral Pre-School Hearing Screening  
Serpanos & Jarmel, 2007

Figure 1. Pass/refer pure-tone and tympanometry screening outcomes. Total number of children screened = 34,979. CNT = could not test.

- **PASSED** 82% (n = 28,642)
- **REFERRED** 18% (n = 6,337)
  - Pure tone 2% (n = 663)
  - Pure tone-CNT 3% (n = 1,185)
  - Tympanometry 6% (n = 2,006)
  - Pure tone & tympanometry 7% (n = 2,483)
Evidence-Based Problems with
Behavioral Pre-School Hearing Screening:

  - N = 1462 3 and 4 year old children in Head Start programs
  - Followed ASHA 1997 Guidelines for pure tone screening, tympanometry, plus stoscopy
  - 54% passed initial screening with all three procedures
  - Pass rate for each procedure
    - 90% for otoscopy
    - 71% for tympanometry
    - 71% for pure tones (29% failure rate)
  - Rescreen pass rate was 76%
  - Only about 71% received recommended evaluation
  - Hearing status of 18% of the children never determined
Behavioral Pre-School Hearing Screening in Physicians’ Office Setting

  - N = 1061 children age 3 to 19 years
  - “Convenience sample” with medical insurance coverage
  - Eight pediatric practices in Alabama
    - 5 nonacademic (private) practices
    - 3 academically affiliated practices
  - Screening in examination room (trained research assistant)
  - 95% conventional screening and 5% play audiometry
  - PT screening at 20 dB HL for 1000, 2000, and 4000 Hz
  - Screening audiometers with supra-aural earphones
Behavioral Pre-School Hearing Screening Screening in Physicians’ Office Setting

Halloran et al (2005)

- Completion of hearing screening
  - Age
    - 3 years: 55% (45% unable to complete screening)
    - 4 years: 93%
    - 5 years: 97%
    - 6 years: 100%
  - Pediatricians didn’t refer the children) for
    - 59% of the children failing the screening
    - 73% of the children with CNT results
Behavioral Pre-School Hearing Screening in Physicians’ Office Setting … Follow Up Study

  - Of the total of 1061 children undergoing hearing screening, a group of 130 children received complete audiological evaluation
  - “With audiological evaluation used as the gold standard”
    - Sensitivity was 50%
    - Specificity was 78%
    - None of the 28 children who could not be tested had hearing loss
Behavioral Pre-School Hearing Screening in Physicians’ Office Setting

Halloran et al (2005)

“A national survey of general pediatricians found that guidelines were more likely to be followed if they were:

● Simple
● Feasible
● And demonstrated improved outcomes”

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- Introduction to Early Hearing Detection and Intervention (EHDI)
- Guidelines for preschool hearing screening and limitations of pure tone screening
- Summary of research in support of OAEs in preschool hearing screening
- Evidence-based strategy for applying OAEs in preschool hearing screening
- Summary, questions & answers:
Summary of Research in Support of OAEs in Preschool Hearing Screening

Summary of Research in Support of OAEs in Preschool Hearing Screening


- Methods
  - 198 preschool children age 3 to 6 years (mean 4.5 years)
  - Testing unsuccessful for another 2 children (PTs only)
  - Screening procedures
    - DPOAEs
    - PT screening with conditioned play (block in bucket)
  - Data collected by audiology and SLP grad students in 8 different preschool facilities
  - Protocol consistent with ASHA 1997 guidelines
Hearing Screening Time for DPOAEs versus Pure Tone Technique in Pre-School Children
(Kreisman et al, 2013)

Figure 1. Mean time to complete each screening protocol.
Hearing Screening Pass/Fail Data for DPOAEs versus Pure Tone Technique in Pre-School Children (Kreisman et al, 2013)

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Pass</th>
<th>Fail</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPOAE (1-5 kHz)</td>
<td>134</td>
<td>64</td>
<td>198</td>
</tr>
<tr>
<td>DPOAE (2-5 kHz)</td>
<td>141</td>
<td>57</td>
<td>198</td>
</tr>
<tr>
<td>Pure-Tone (1,2,4 kHz)</td>
<td>175</td>
<td>21</td>
<td>196</td>
</tr>
</tbody>
</table>

Note. DPOAE=Distortion Product Otoacoustic Emissions. Two children would not cooperate to be screened using pure tones.
Summary of Research in Support of OAEs in Preschool Hearing Screening: Advantages of OAEs

- Objective and not dependent on child’s
  - Behavioral response
  - Cognition
  - Language level or native language
- Painless and even no discomfort
- Reliable
- Efficient and quick to administer (< 4 minutes)
- Simple to administer with low level of technical skill …Does not require an audiologist
- Measurement doesn’t require acoustically treated environment
- Hand-held and portable equipment
- Test outcome is documented electronically or in printout
The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening

- Introduction to Early Hearing Detection and Intervention (EHDI)
- Guidelines for preschool hearing screening and limitations of pure tone screening
- Summary of research in support of OAEs in preschool hearing screening
- Evidence-based strategy for applying OAEs in preschool hearing screening
- Summary, questions & answers:
The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening: New Strategy Using OAEs, Tympanometry, and Acoustic Reflexes
The Important Role of OAEs in Pre-School Hearing Screening: Combining OAEs, Tympanometry, and Acoustic Reflexes

- Objective and not dependent on child’s behavioral response, cognition, developmental age, or language level
- Reliable
- Efficient and quick to administer (< 4 minutes)
- Simple to administer with low level of technical skill
- Does not require an audiologist
- Does not require an acoustically treated test environment
- Hand-held and portable equipment
- Test outcome is documented electronically or in printout
- Sensitive measure of
  - Middle ear function
  - Cochlear (outer and inner hair cell) function
  - ANSD
Year 2007 Joint Committee on Infant Hearing (JCIH): Protocol for Evaluation of Hearing Loss In Infants from Birth to 6 months

- Child and family history
- Evaluation of risk factors for congenital hearing loss
- Parental report of infant’s responses to sound
- Clinical observation of infant’s auditory behavior
- Audiological assessment
  - Auditory brainstem response (ABR)
  - Otoacoustic emissions (distortion product or transient OAEs)
  - Tympanometry with 1000 Hz probe tone
  - Supplemental procedures, e.g.,
    - Electrocochleography (ECoG)
    - Auditory steady state response (ASSR)
    - Acoustic reflex measurement (for 1000 Hz probe tone)
Acoustic Stapedial Reflex Pathways According to Erick Borg

The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening: 

*Acoustic Reflexes in Neonates*

  - 66 full term infants
  - Acoustic reflexes recorded with 1000 Hz probe tone
  - Tone and BBN stimuli
  - All neonates had acoustic reflexes
**Acoustic Reflexes in Neonates**

(Kei J. Acoustic stapedial reflexes in healthy neonates: normative data* and test-retest reliability. JAAA, 23, 2012)

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Median ART (dB HL)</th>
<th>90% Range</th>
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<tbody>
<tr>
<td>500 Hz</td>
<td>80</td>
<td>70 - 95</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>70</td>
<td>60 - 85</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>65</td>
<td>50 - 80</td>
</tr>
<tr>
<td>BBN</td>
<td>55</td>
<td>50 – 75</td>
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</table>

* *N = 68 ears*
Simplified SPAR (Sensitivity Prediction by the Acoustic Reflex)

The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening: A New Feasible and Evidence-Based Approach

<table>
<thead>
<tr>
<th>Birth to 4 Years</th>
<th>&gt; 4 Years</th>
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<tbody>
<tr>
<td><strong>DPOAES</strong></td>
<td>Pure tone screening at 20 dB or PASS for previous hearing screening? Follow birth to 4 year objective test protocol.</td>
</tr>
<tr>
<td>L1 = 65 dB; L2 = 55 dB</td>
<td></td>
</tr>
<tr>
<td>2000 – 5000 Hz</td>
<td></td>
</tr>
<tr>
<td>PASS = DP &gt; 0 dB SPL</td>
<td></td>
</tr>
<tr>
<td><strong>Fail?</strong></td>
<td>Previous FAIL outcome or no documented hearing screening?</td>
</tr>
<tr>
<td><strong>Immittance measures</strong></td>
<td>Follow 2011 AAA Guidelines</td>
</tr>
<tr>
<td>Tympanometry</td>
<td>(Pure tone screening at 20 dB HL)</td>
</tr>
<tr>
<td>ART for BBN</td>
<td></td>
</tr>
<tr>
<td>PASS = type A; BBN &lt; 80 dB</td>
<td></td>
</tr>
<tr>
<td><strong>Otoscopy as indicated</strong></td>
<td></td>
</tr>
</tbody>
</table>


OAE Screening in Pre-School and School Age Children: Criterion for PASS versus REFER
(Data for adults and older children from Gorga, Stover & Neely, 1996)
# Creating a Preschool DPOAE Screening Protocol

*(GSI Corti)*

<table>
<thead>
<tr>
<th>Options</th>
<th>Protocol Name</th>
<th>Number of Frequencies</th>
<th>Frequencies</th>
<th>Average Time</th>
<th>Allow Change</th>
<th>Pass Criteria</th>
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<tbody>
<tr>
<td><strong>DP Diagnostic</strong></td>
<td>DP 1.5-6.0</td>
<td>6</td>
<td>1.5,2,3,4,5,6</td>
<td>4 sec</td>
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<td>Optional</td>
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<tr>
<td></td>
<td>DP 1.6-8.0</td>
<td>12</td>
<td>1.6,2,2.5,3.2,3.6,4,4.5,5,5.6,6,6.3,7.1,8</td>
<td>4 sec</td>
<td>Yes</td>
<td>Optional</td>
</tr>
<tr>
<td></td>
<td>DP 1.5-12</td>
<td>12</td>
<td>1.5,2,3,4,5,6,78,9,10,11,12</td>
<td>4 sec</td>
<td>Yes</td>
<td>Optional</td>
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<tr>
<td></td>
<td>DP 2.0-5.0</td>
<td>4</td>
<td>2,3,4,5</td>
<td>4 sec</td>
<td>Yes</td>
<td>Optional</td>
</tr>
<tr>
<td></td>
<td>DP 4S</td>
<td>4</td>
<td>2,3,4,5</td>
<td>4 sec</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
New Strategy for Pre-School Hearing Screening with OAEs, Tympanometry, and Acoustic Reflexes

Pass ?

- Tympanometry + ART for BBN
  - Pass All Tests?
    - No Follow Up
    - Repeat Fail/Abnormal?
      - Medical Referral

Otoscopy

- Fail/Abnormal?
  - Repeat Fail/Abnormal?
    - Medical Referral

- Tympanometry
  - Pass ?
    - 2nd Attempt
      - Re-Test in < 1 Month
        - Pure Tone Screen (if feasible with age)

DPOAEs
The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening: Summary, Questions & Answers

- Preschool hearing screening is essential for successful EHDI
- Pure tone technique is not feasible for young preschool children
- OAEs offer an evidence-based technique for preschool hearing screening
- OAEs in combination with aural immittance measures permit on site follow-up assessment for children failing preschool screening