If you are viewing this course as a recorded course after the live webinar, you can use the scroll bar at the bottom of the player window to pause and navigate the course.

This handout is for reference only. It may not include content identical to the powerpoint. Any links included in the handout are current at the time of the live webinar, but are subject to change and may not be current at a later date.
Introduction: Why early diagnosis of infant hearing loss is important

Review of stimuli used to elicit the ABR in infants and young children

Test protocol for ABR recording in children

Measurement and analysis of tone burst and bone conduction ABRs

Bone conduction ABRs

Techniques for un-sedated ABRs and sedation options

Discussion, questions, & answers
Universal Newborn Hearing Screening and Early Identification of Hearing Loss in Infants: Turning Point in the United States of America (March 1993)

- Evidence in support of benefits of early identification on speech and language development (for pediatricians)
- Recognition of economic consequences of hearing loss (by policy makers)
- Emergence of technology for automated auditory brainstem response (ABR) and otocoustic emissions (OAEs)
- Evidence of low failure rates (< 4%) and automated ABR and OAE techniques
- Relatively low cost of identifying infants with hearing loss versus expense of intervention with later identification
- Identified research questions about benefits of early intervention

UNHS Rationale: Effects of infant hearing loss
NIH Consensus Statement “Early Identification of Hearing Impairment in Infants and Young Children” (March 1-3, 1993)

“There is general agreement that hearing impairment should be recognized as early in life as possible, so the remediation process can take full advantage of the developing sensory systems and so that the child can enjoy normal social development.”

Recommendation: Universal Newborn Hearing Screening
Christie Yoshingaga-Itano:
Early Intervention (6 months after birth) is Important


- N = 72 children with HL identified by 6 months and N = 78 children identified later.
- All children received intervention services with 2 months of identification.
- Conclusion: “Significantly better language development was associated with early ID of hearing loss and early intervention . . . the language advantage was found across all . . . degrees of hearing loss.”

Language of Early and Later Identified Children with Hearing Loss
## American Academy of Pediatrics
Newborn and Infant Hearing Loss: Detection and Intervention

- **Pediatrics 103 (2): 527-529, 1999 (February)**
- **Screening**
- **Tracking & Followup**
- **Evaluation**
- **Abstract:** “This statement endorses the implementation of universal newborn hearing screening. In addition, the statement reviews the primary objectives, important components, and recommended screening parameters that characterize an effective universal newborn hearing screening program.”

## Application of ABR in Objective Assessment of Infant Hearing

- **Introduction:** Why early diagnosis of infant hearing loss is important
- **Review of stimuli used to elicit the ABR in infants and young children**
- **Test protocol for ABR recording in children**
- **Measurement/analysis of tone burst and bone conduction ABRs**
- **Bone conduction ABRs**
- **Techniques for un-sedated ABRs and sedation options**
- **Discussion, questions, & answers**
Year 2007 Joint Committee on Infant Hearing (JCIH): Protocol for Evaluation for 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. Behavioral observation alone is not adequate for determining whether hearing loss is present in this age group, and is not adequate for the fitting of amplification devices.”

- Audiological assessment
  - Auditory brainstem response (ABR)
    - Click-evoked ABR with rarefaction and condensation single-polarity stimulation if there are risk factors for auditory neuropathy
    - Frequency-specific ABR with air-conduction tone bursts
    - Bone-conduction stimulation (as indicated)
  - Otoacoustic emissions (distortion product or transient OAEs)
  - Tympanometry with 1000 Hz probe tone
  - Supplemental procedures, e.g.,
    - Electrocochleography (ECochG)
    - Auditory steady state response (ASSR)
    - Acoustic reflex measurement (for 1000 Hz probe tone)

The Unavoidable Trade-Off Between Duration and Frequency-Specificity in ABR Stimulation
(Figure from Hall JW III. Introduction to Audiology Today, 2014)

- Time Domain
- Frequency Domain
- 1000 Hz Pure Tone
- 1000 Hz Tone Burst
- Click
- 0.1 ms (100 μs)

Time (ms) 0 1 2 3 4 5 6 7
Frequency (Hz) 250 500 1000 2000 4000
Click-Evoked ABR Lacks Frequency-Specificity: Should you stick with the click?

Diagnostic Value of the Click-Evoked ABR: Differentiation Among Types of Auditory Dysfunction
Why it’s a good strategy to begin the ABR assessment with click stimulation
- Waveform analysis permits differentiation among types of hearing loss
- Waveform analysis indicates test ear (presence of wave I)
- Auditory neuropathy spectrum disorder (ANSD) can be ruled out or identified
- Findings help to determine next steps in the assessment, e.g.,
  ✓ Bone conduction ABR or tympanometry?
  ✓ ASSR?
- Only requires a few minutes of test time
- Recommended by the 2007 Joint Committee on Infant Hearing
Frequency-Specific Stimuli Available for Eliciting ABR (and ASSR)

Introduction: Why early diagnosis of infant hearing loss is important
Review of stimuli used to elicit the ABR in infants and young children
Test protocol for ABR recording in children
Measurement and analysis of tone burst and bone conduction ABRs
Bone conduction ABRs
Techniques for un-sedated ABRs and sedation options
Discussion, questions, & answers

Application of ABR in Objective Assessment of Infant Hearing
## Test Protocol for ABR in Children: Stimulus Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selection</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transducer</td>
<td>ER-3A inserts</td>
<td>Numerous infant advantages</td>
</tr>
<tr>
<td>Type</td>
<td>Click stimuli, Tone bursts</td>
<td>Available on all systems</td>
</tr>
<tr>
<td>Frequencies</td>
<td>1, .5, 4, 2 K Hz</td>
<td>Sequence varies clinically</td>
</tr>
<tr>
<td>Duration</td>
<td>Click 0.1 ms, Tone Bursts 2-0-2 cycles</td>
<td>Equivalent intensity for each frequency 0 plateau &lt; spectral splatter</td>
</tr>
<tr>
<td>TB Ramping (window)</td>
<td>Blackman</td>
<td>Less spectral splatter</td>
</tr>
</tbody>
</table>

## Test Protocol for ABR in Children: Acquisition Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selection</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artifact reject</td>
<td>On</td>
<td>Minimize muscle artifact Weighted averaging of all data</td>
</tr>
<tr>
<td>Analysis time</td>
<td>20 ms</td>
<td>Encompass delayed wave Vs and SN10 after wave V</td>
</tr>
<tr>
<td>Sweeps</td>
<td>1000 or 2000</td>
<td>Produce adequate SNR Automated detection of adequate response based on SNR</td>
</tr>
<tr>
<td>Reliability</td>
<td>2 or 3 runs</td>
<td>“If it doesn’t replicate, you must investigate!”</td>
</tr>
</tbody>
</table>
Test Protocol for ABR in Children: Acquisition Parameters (2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selection</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrode type</td>
<td>Disc &amp; ear clip or disposable</td>
<td>Ease of application</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infection prevention</td>
</tr>
</tbody>
</table>
| Electrode location | Fz - Ai  
|                 | Fpz ground                    | Optimal infant response                                |
|                 |                               | Good for BC stimulus                                   |
|                 |                               | Permits ipsi/contra recording                          |
| Filter settings | 30 - 3000 Hz  
|                 | No notch filter               | Encompass infant spectrum                              |
| Artifact reject | On                            | Minimize muscle artifact                                |
|                 |                               | Weighted averaging is available on some devices        |

Application of ABR in Objective Assessment of Infant Hearing

- Introduction: Why early diagnosis of infant hearing loss is important
- Review of stimuli used to elicit the ABR in infants and young children
- Test protocol for ABR recording in children
- Measurement and analysis of tone burst and bone conduction ABRs
- Bone conduction ABRs
- Techniques for un-sedated ABRs and sedation options
- Discussion, questions, & answers
Steps in Accurate Estimation of Auditory Thresholds

- With ABR system, obtain average normal behavioral thresholds (from 3 to 5 normal hearing adults) for click and each tone burst signal
  - Minimally click plus 500, 1000, 2000, and 4000 Hz
  - Calculate “dial” reading that is equivalent to 0 dB nHL
  - With ABR system
  - In typical test environment (s)
- ABR thresholds in dB nHL are not equal to pure tone hearing thresholds in dB HL
  - Subtract 10 dB from ABR threshold to estimate auditory threshold (edB HL)
- Plot estimated auditory thresholds on “tone burst ABR audiogram”

Correction Factors for Converting ABR Thresholds in dB nHL to Estimated Behavioral Thresholds in dB HL (or EHL)

<table>
<thead>
<tr>
<th>Source</th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCEHP</td>
<td>-15 dB</td>
<td>-10 dB</td>
<td>-5 dB</td>
<td>0 dB</td>
</tr>
<tr>
<td>Bagatto (2006)</td>
<td>-20 dB</td>
<td>-15 dB</td>
<td>-10 dB</td>
<td>-5 dB</td>
</tr>
<tr>
<td>Hall (2007)</td>
<td>-15 dB</td>
<td>-10 dB</td>
<td>-10 dB</td>
<td>-10 dB</td>
</tr>
</tbody>
</table>

Note: According to Stapells (2000), ABR thresholds “overestimate” behavioral thresholds by 10 to 20 dB for normal hearers and 5 to 15 dB for patients with sensory hearing loss.
FREQUENCY-SPECIFIC AUDITORY BRAINSTEM RESPONSE (ABR): Relation to Audiogram (Oates & Stapells, 1998)

Cochlear Excitation Patterns for Click versus Narrow Band Stimulation

Continuous, narrow band stimuli

Upward spread of excitation
Downward spread of excitation

Scala Vestibuli
Scala Tympani
Basilar membrane
Apex
Stapes
Round Window

Traveling Wave
Transient, broad band stimuli
Temporal Compensation via Input Compensation
(Courtesy of Claus Elberling)

Chirp Temporal Waveform

Low frequencies
High frequencies
Conventional Click versus CE Chirp Evoked ABR
(1 year 4 month old boy with speech & language delay who failed hearing screening in nursery. Parents do not speak English)

85 dB nHL Click, rarefaction, 21.1/sec
I = 1.46 ms
V = 6.67 ms
I-V = 5.21 ms

45 dB nHL Click
25 dB nHL Click
20 dB nHL Click
20 dB nHL CE Chirp
15 dB nHL Click
15 dB nHL CE Chirp

4000 Hz Conventional versus Chirp Evoked ABR

Left Ear
85 dB nHL
Tone Burst

40 dB nHL
Tone Burst

30 dB nHL
Tone Burst

30 dB nHL, Chirp Tone Burst

25 dB nHL, Tone Burst

25 dB nHL, Chirp Tone Burst

15 dB nHL, Chirp Tone Burst
4000 Hz Chirp Evoked ABR
Stimulus rate = 37.7/sec
Total sweeps = 2622; Total test time = 69.5 seconds

Right Ear
80 dB nHL
684 sweeps

40 dB nHL
456 sweeps

20 dB nHL
570 sweeps

15 dB nHL
912 sweeps

Electrophysiological Estimation of the Audiogram:
One year 4 month boy
peRETSPLs:  
CE-Chirp Octave Bands vs. Tone Bursts

- ISO 389-6: 2-1-2 Tone Burst peRETSPLs (blue = tone bursts)
- 3A Insert Earphones using 711 ear simulator
- Range of 0.4 to 1.8 dB difference


Acoustic Spectrum:  
CE-Chirp Octave Bands vs. Tone Bursts

Courtesty of East Carolina University
Wave V amplitudes were significantly greater at 60, 40, 20 dB nHL.
Greater amplitudes are consistent with previously published research.

Click versus Tone Burst ABRs: Differences in Morphology and Latency

Examples of ABR Elicited with Tone Burst Stimuli: Click ABR
(1.5 year child with language delay; parents from Thailand)

75 dB nHL to 40 dB HL (Why waste time with other intensity levels?)

25 dB nHL = 15 dB HL (Why go lower?)
Examples of ABR Elicited with Tone Burst Stimuli: 4000 Hz stimulus

Application of ABR in Objective Assessment of Infant Hearing

- Introduction: Why early diagnosis of infant hearing loss is important
- Review of stimuli used to elicit the ABR in infants and young children
- Test protocol for ABR recording in children
- Measurement/analysis of tone burst and bone conduction ABRs
- Bone conduction ABRs
- Techniques for un-sedated ABRs and sedation options
- Discussion, questions, & answers
Bone Conduction Auditory Brainstem Response
(Case: 6 year old girl with Treacher Collins syndrome and bilateral aural atresia. Previous diagnosis: Probable left "dead ear")

Anatomy of the Skull in Infants:
An Advantage in Ear Specific Bone Conduction ABR
Two-Channel Bone Conduction ABR Recording: Applying ECochG Principles to Verify the Test Ear

Ipsi Channel
Wave I

Contra Channel
No Wave I

ABR: Protocol for Bone Conduction

- B-70 or B-71 bone vibrator
- Mastoid placement
  - 10 dB increase in intensity
  - Less electrical interference with recording electrodes
- Leave insert earphones in ear canals after air conduction ABR
- Increased distance between inverting electrode and transducer
- Alternating click stimuli to minimize stimulus artifact
- Slower rate (e.g., 11.1/sec) as needed to enhance wave I
- 30 to 3000 Hz (low frequencies enhance response amplitude)
- Begin near maximum intensity level (about 50 dB nHL)
- Identify wave I in ipsilateral array to verify test ear
- Plot latency/intensity function for wave V for BC vs. AC

continued
Bone Conduction: Effect of Transducer Factors

Example of Estimation of Air-Bone Gap with ABR
Application of ABR in Objective Assessment of Infant Hearing

- Introduction: Why early diagnosis of infant hearing loss is important
- Review of stimuli used to elicit the ABR in infants and young children
- Test protocol for ABR recording in children
- Measurement/analysis of tone burst and bone conduction ABRs
- Bone conduction ABRs
- Techniques for un-sedated ABRs and sedation options
- Discussion, questions, & answers

Un-Sedated ABR Measurement: Techniques

- Non-medical techniques
  - Sleep deprivation
  - Record ABR immediately after feeding
  - Bean bag “bed” to minimize movement
  - Benedryl (with pediatrician approval)
  - Melatonin
**Un-Sedated ABR Measurement: Melatonin**

- Selected publications on use of melatonin to induce sleep in medicine

---

**ABR in the Clinic with Conscious Sedation (e.g., chloral hydrate): No Longer an Option in the USA**
ABR in Ambulatory Surgical Center with Light Anesthesia (e.g., Propofol)

Breaking News from CNN
Concerns about Anesthesia in Children
August 20, 2012
Anesthesia in young kids may carry developmental risks. While surgery carries risks for anyone, “going under” can have some particular risks for the very young. A study coming out in the September issue of Pediatrics finds that children who have anesthesia before the age of 3, are at a higher risk for developmental delay issues later in life. The study looked at more than 2,600 children in Australia who were tracked as part of the Raine Study. Authors found that by the age of 10, children who’d been exposed to anesthesia at a young age were more than twice as likely to have developmental issues with listening and speaking comprehension.
Auditory Steady State Response (ASSR) for Objective Frequency-Specific Estimation of Severe-to-Profound Hearing Loss: A Variety of Clinical Devices

Introduction: Why early diagnosis of infant hearing loss is important

Review of stimuli used to elicit the ABR in infants and young children

Test protocol for ABR recording in children

Measurement and analysis of tone burst and bone conduction ABRs

Bone conduction ABRs

Techniques for un-sedated ABRs and sedation options

Discussion, questions, & answers

Application of ABR in Objective Assessment of Infant Hearing
Thank You!
Questions?