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Update on Auditory Evoked Responses: Evidence-Based ABR Protocol for Infant Hearing Assessment

Presenter: James W. Hall III, Ph.D.
Moderator: Carolyn Smaka, AuD, Editor in Chief, AudiologyOnline

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Update on Auditory Evoked Responses: Evidence-Based Protocol for Infant Hearing Assessment

James W. Hall III, Ph.D.
Professor
Salus University
Professor
University of Hawaii
Extraordinary Professor
University of Pretoria
South Africa

jwhall3phd@gmail.com www.audiologyworld.net

Learning Objectives

- As a result of this Continuing Education Activity, participants will be able to:
  - Identify 5 evidence-based stimulus parameters for ABR measurement in infants.
  - Identify 5 evidence-based acquisition parameters for ABR measurement in infants.
  - List 3 practical steps for minimizing ABR test time.
Update on Auditory Evoked Responses: Evidence-Based Protocol for Infant Hearing Assessment

- What do we mean by “evidence-based”?
- Historical perspective
- The “crosscheck principle” and ABR
- ABR stimulus parameters
- ABR acquisition parameters
- Saving precious test time
- Conclusions
- Questions and answers

Best Practice is Evidence-Based Practice (EBP)

“Those who fall in love with practice without science are like a sailor who steers a ship without a rudder or compass, and who can never be certain whither he is going.”

Leonardo Da Vinci (1452-1519)
Evidence-Based Practice (EBP) is Best Practice

Best Practice Follows Clinical Practice Guidelines

- Evidence-based practice is “the integration of best research evidence with clinical expertise and patient values” (Sackett et al. Evidence-Based Medicine: How to practice and teach EBM. London: Churchill, 2000, p. 1)
- EBP is a five step process
  - Focused clinical question
  - Evidence is sought to answer the question
  - Clinician evaluates the quality of evidence
  - Clinician must integrate the evidence with the patient’s clinical findings and preferred outcome to develop intervention plan
  - Document outcome and identity ways to improve it

US Preventative Services Task Force
(www.fpnotebook.com/prevent/epi)

- Level I: Randomized control trial
- Level II: Non-randomized control trial
- Level III: Cohort or case-control study
- Level IV: Ecological or descriptive studies
- Level V: Opinions of respected authorities based on
  - Clinical experience
  - Descriptive studies or
  - Reports of expert committees
Year 2007 JCIH Position Statement
Protocol for Evaluation for Hearing Loss In Infants
and Toddlers 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
- 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)
  - Auditory steady state response (ASSR) is optional
  - Otoacoustic emissions (distortion product or transient OAEs)
  - Tympanometry with 1000 Hz probe tone

*“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.”*

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The First Comprehensive Description of the Auditory Brainstem Response (ABR) in Humans

Jewett DL & Williston JS. Auditory evoked far fields averaged from the scalp of humans. Brain 4, 1971

Auditory Brainstem Response in Infant Hearing Assessment: Beginnings in the 1980s

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The Cross-Check Principle in the Diagnosis of Hearing Loss in Children
(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)
The Cross-Check Principle Pediatric Audiology
(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)

Test Battery:
- Behavioral audiometry
- Immittance (impedance) measurements
  - Tympanometry
  - Acoustic reflexes (contralateral only with SPAR)
- Auditory brainstem response (brainstem-evoked response audiometry or BSER)
  - Click stimulus air conduction
  - Click stimulus bone conduction

"We have found that simply observing the auditory behavior of children does not always yield an accurate description of hearing loss."

"The basic operation of this principle is that no result be accepted until it is confirmed by an independent measure."

"As long as audiologists are willing to accept the results of a single test measure they will continue to misdiagnosis and mismanage some children."
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The Cross-Check Principle in Audiology Today
40-Years of Clinical Experience

- Behavioral Audiometry
- Otoacoustic Emissions (OAEs)
- Aural Immittance Measurements
  - Tympanometry
  - Acoustic Reflexes
- Auditory Brainstem Response (ABR)
  - Air- and Bone Conduction Stimulation
  - Click, Tone Burst and Chirp Stimulation
- Auditory Steady State Response (ASSR)
- Electrocochleography (ECochG)
- Cortical Auditory Evoked Responses
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**Update on Auditory Evoked Responses: Evidence-Based Protocol for Infant Hearing Assessment**

*Stimulus Parameters*
Evidence-Based Frequency-Specific ABR Test Protocol:

**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></td>
<td>B71 or B81</td>
<td>Bone oscillator as needed</td>
</tr>
<tr>
<td>Type</td>
<td>Clicks</td>
<td>R/O ANSI</td>
</tr>
<tr>
<td></td>
<td>Tone bursts</td>
<td>Available on all systems</td>
</tr>
<tr>
<td></td>
<td>Chirp stimuli</td>
<td>Topic of March 16 AO course</td>
</tr>
<tr>
<td>Mode of</td>
<td>Air-conduction</td>
<td>Always</td>
</tr>
<tr>
<td>Presentation</td>
<td>Bone-conduction</td>
<td>As indicated</td>
</tr>
<tr>
<td>Polarity</td>
<td>Rarefaction</td>
<td>Condensation as needed</td>
</tr>
<tr>
<td>Ramping (window)</td>
<td>Blackman</td>
<td>Less spectral splatter</td>
</tr>
</tbody>
</table>

ABR Transducer Options for Pediatric ABR Recordings:

*Insert Earphone with Adaptor*
ABR Measurement in Infants and Young Children:
Advantages of Insert (ER-3A) versus Supra-Aural Earphones

- General
  - Increased inter-aural attenuation
  - Increased ambient noise attenuation
  - Elimination of ear canal collapse
  - Increased patient comfort
  - Improved aural hygiene
  - More precise placement (increased reliability)

- ABR specifically
  - Reduced transducer ringing
  - Reduced stimulus artifact (with separation of transducer from inverting electrode)

Stimulus Factors in ABR Measurement:
*Rationale for Rarefaction Stimulus Polarity*

Stimulus Polarity and Activation of the Auditory Brainstem Response (ABR)
Frequency-Specific ABRs with Tone Burst Stimuli: *
Blackman Onset Window (Ramp) is Optimal*

Ear Specific Bone Conduction Auditory Assessment is Feasible with ABR
Two-Channel Bone Conduction ABR Recording: Applying ECochG Principles to Verify the Test Ear (Without the Need for Masking of the Contralateral Ear)

Evidence-Based Frequency-Specific ABR Test Protocol: Stimulus Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selection</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate</td>
<td>Click: 21.1/sec</td>
<td>Record wave I in less time</td>
</tr>
<tr>
<td></td>
<td>TB: 37.7/sec</td>
<td>Record wave V in less time</td>
</tr>
<tr>
<td>Frequencies</td>
<td>.5, 1, 2, 4 K Hz</td>
<td>Sequence varies clinically</td>
</tr>
<tr>
<td>Duration</td>
<td>2-0-2 cycles</td>
<td>Equal intensities; &lt; splatter</td>
</tr>
<tr>
<td>Ramping</td>
<td>Blackman</td>
<td>More frequency-specific</td>
</tr>
<tr>
<td>Intensity</td>
<td>dB nHL</td>
<td>Calibration in peRETSPL plus normal behavioral thresholds for each stimulus</td>
</tr>
</tbody>
</table>
Auditory Brainstem Response Measurement: Rationale for Stimulus Rates
(21.1/sec for Clicks; 37.7/sec for Tone Bursts)

Auditory Brainstem Response Measurement: Stimulus Parameters ... Duration

Stimulus Duration

Intensity

Time in Milliseconds
Frequency-Specific ABRs with Tone Burst Stimuli:  
*Rationale for No Plateau (2-0-2 cycles)*

Strengths and Weaknesses of Click-Evoked ABR:  
Diagnostically Useful but Limited Frequency-Specificity
Tone Burst Stimuli Acoustic Spectrum:
Frequency-Specific But Not A Pure Tone

Effect of Stimulus Intensity on
Auditory Brainstem Response Wave V
Latency/Intensity Function
Effect of Stimulus Intensity on ABR: Changes in Morphology


N = 177 (309 ears) Average age at ABR = 24 months

ABR thresholds underestimate hearing levels for > moderate hearing loss
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### Evidence-Based Frequency-Specific ABR Test Protocol: 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</td>
</tr>
<tr>
<td>Analysis time</td>
<td>15-ms</td>
<td>Click, 4000 Hz, 2000 Hz</td>
</tr>
<tr>
<td></td>
<td>20-ms</td>
<td>1000 Hz and 500 Hz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Encompass delayed wave V and SN10 after wave V</td>
</tr>
<tr>
<td>Sweeps</td>
<td>Variable</td>
<td>To produce an SNR of &gt; 3:1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>To increase test efficiency</td>
</tr>
</tbody>
</table>
| Reliability      | 2 or 3 runs | *"If the waves don’t replicate, you must investigate!"*

### Evidence-Based Frequency-Specific ABR Test Protocol: Selection of Analysis Time

- ABR wave V latency for click stimulus at 65 dB nHL: $\approx 6.0$-ms
- Decrease in intensity to 20 dB nHL: $+3$-ms
- Conductive hearing loss component of 50 dB: $+2$-ms
- Age related latency increase for term infant: $+1$-ms
- Latency increase with hypothermia (4 degrees): $+1$-ms
- Pre-stimulus baseline: $+1$-ms

Total = 14-ms

**Goal:** ABR Wave V Midway in the Analysis Time
Auditory Brainstem Response Measurement: 
*Signal Averaging ... Rationale for the Number of Sweeps*

Signal-to-Noise Ratio (SNR) =

\[
\text{SNR} = \frac{\text{Signal Amplitude} \times \text{Number of Averages}}{\text{Noise Amplitude}}
\]

Goal = SNR > 3:1
*(ABR wave V: Residual Noise)*

Factors:
- Signal = Stimulus Intensity, Hearing Status, Chirp
- Noise = Muscle and Electrical Activity

<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</td>
<td>Disposable = &lt;</td>
</tr>
<tr>
<td>infection</td>
<td>or disposable</td>
<td></td>
</tr>
<tr>
<td>Electrode location</td>
<td>Fz - Ai</td>
<td>Optimal infant response</td>
</tr>
<tr>
<td></td>
<td>Fpz ground</td>
<td>Good for BC stimulus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Permits ipsi/contra meas't</td>
</tr>
<tr>
<td>Filter settings</td>
<td>30 - 3000 Hz</td>
<td>Encompass infant spectrum</td>
</tr>
<tr>
<td></td>
<td>No notch filter</td>
<td></td>
</tr>
<tr>
<td>Artifact reject</td>
<td>On</td>
<td>Minimize muscle artifact</td>
</tr>
</tbody>
</table>
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Simple Techniques for Saving Valuable Time in Frequency-Specific Estimation of an Audiogram with Tone Burst ABRs (*Test time of 30 minutes or less*)

- Be prepared to begin ABR as soon as the child is asleep
  - Equipment is set up with patient information
  - Electrodes are handy with electrode gel or paste
  - Insert earphones are ready with proper size tips
- Record ABR in conditions that optimize the SNR
  - Sleeping, sedated, or anesthetized child
  - Low and balanced electrode impedance
  - Little or no electrical artifact
  - Deep fitting insert earphone (minimize acoustic noise)
  - Chirp stimuli
- Stimulus presentation rate of about >37.7/sec
- Immediately trouble-shoot if the ABR findings are unexpected

Think ahead to the next step in the assessment while signal averaging ... don't do your thinking between periods of data collection

At high stimulus intensities
  - Discontinue signal averaging as soon as a clear response is detected with minimum criteria for stimuli or sweeps (e.g., 1000)
  - Immediately replicate with even fewer averages
  - Calculate latencies and amplitudes while also collecting data at the next intensity level

Drop the stimulus intensity level as quickly as possible to near threshold (e.g., from 80 dB nHL down to 40 dB nHL if the ABR has a wave I and wave V)

After hearing thresholds are estimated with click stimuli, begin presenting subsequent tone burst stimuli at intensity levels 20 to 30 dB above anticipated ABR threshold

Don't replicate "flat" ABR tracings
Resource

- eHandbook of Auditory Evoked Responses (2015)
- Procedures and protocols for recording ECochG, ABR, ASSR, AMLR, ALR, and P300
- eBook available from Kindle Direct Publishing (Amazon.com)
  http://www.amazon.com/dp/B0145G2FFM