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Update on Auditory Evoked Responses: Value of Chirp Stimuli in ABR/ASSR Measurement

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

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Update on Auditory Evoked Responses: Value of Chirp Stimuli in ABR/ASSR Measurement

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Learning Objectives

- As a result of this Continuing Education Activity, participants will be able to:
  - Describe concepts underlying chirp stimuli.
  - Define the role of click versus tone burst stimulation in infant ABR measurement.
  - Identify 3 advantages of chirp stimuli in infant ABR measurement.
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

Update on Auditory Evoked Responses: Value of Chirp Stimuli in ABR/ASSR Measurement

What do we mean by “evidence-based”?  
Introduction to ABR stimulus parameters  
Role of click and tone burst stimulation in infant ABR measurement  
Definition of chirp stimuli  
Advantages of chirp stimuli in infant ABR recordings  
Review of selected recent research findings on chirps  
Questions and answers
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 identify ways to improve it

US Preventative Services Task Force:

Grades of Evidence
(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
Update on Auditory Evoked Responses: Value of Chirp Stimuli in ABR/ASSR Measurement

- What do we mean by “evidence-based”?
- Introduction to ABR stimulus parameters
- Role of click and tone burst stimulation in infant ABR measurement
- Definition of chirp stimuli
- Advantages of chirp stimuli in infant ABR recordings
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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 ANSD</td>
</tr>
<tr>
<td></td>
<td>Tone bursts</td>
<td>Available on all systems</td>
</tr>
<tr>
<td></td>
<td>Chirp stimuli</td>
<td>Larger ABR amplitude</td>
</tr>
<tr>
<td>Mode of Presentation</td>
<td>Air-conduction</td>
<td>Always</td>
</tr>
<tr>
<td></td>
<td>Bone-conduction</td>
<td>As indicated</td>
</tr>
<tr>
<td>Polarity</td>
<td>Rarefaction</td>
<td>Condensation as needed</td>
</tr>
</tbody>
</table>
## 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>

## Update on Auditory Evoked Responses: Value of Chirp Stimuli in ABR/ASSR Measurement

- What do we mean by “evidence-based”?
- Introduction to ABR stimulus parameters
- Role of click and tone burst stimulation in infant ABR measurement
  - Stick with the click and...
  - Be the first with the bursts
- Definition of chirp stimuli
- Advantages of chirp stimuli in infant ABR recordings
- Review of selected recent research findings on chirps
- Questions and answers
Example of A Practice Guideline in Audiology:
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.”

Diagnostic Value of Click-Evoked ABR:
Determining Site of Auditory Dysfunction

- Brainstem
  (ABR, ASSR, ARs)
- Spiral ganglion cells
  (ABR, ECochG)
- IHC - 8th CN Synapse
  (ABR)
- Inner hair cells
  (ECochG, ABR, ASSR, ARs)
- Outer hair cells
  (OAE, ECochG, ARs)
Strengths and Weaknesses of Click-Evoked ABR: Diagnostically Useful but Limited Frequency-Specificity


**Click ABR Threshold versus Pure Tone Hearing Threshold (2 to 4 K Hz)**

\[ N = 77 \]
\[ 71 = < 5 \text{ years} \]

Click ABR Threshold Better Than Pure Tone Threshold
Diagnostic Value of the Click-Evoked ABR:
Differentiation Among Types of Auditory Dysfunction

- Recommend beginning an ABR assessment with click stimuli
- Only requires a few minutes of test time
- Analysis permits differentiation among types of hearing loss
- Waveform analysis indicates test ear (presence of wave I)
- Identification of auditory neuropathy spectrum disorder
- Findings help to determine next steps in the assessment, e.g.,
  - Bone conduction ABR
  - Tympanometry
  - ASSR
- Recommended by the:
  - 2007 Joint Committee on Infant Hearing (USA)
  - International clinical guidelines (e.g., UK, Canada, Australia)
Estimation of Frequency-Specific Auditory Thresholds with Tone Burst ABRs: Initial Data Points for Hearing Aid Fitting or Cochlear Implant Candidacy

FREQUENCY-SPECIFIC AUDITORY BRAINSTEM RESPONSE (ABR): Relation to Audiogram (Oates & Stapells, 1998)

\[ N = 77 \]
\[ 71 = < 5 \text{ years} \]

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**Frequency Specific Auditory Brainstem Response: Selected References (1)**

Frequency Specific Auditory Brainstem Response: Selected References (2)


Air Conduction Tone Burst ABR Thresholds Minus Behavioral Thresholds in Infants and Young Children with Hearing Loss

*Adapted from Stapells (2011)*

<table>
<thead>
<tr>
<th>Study</th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stapells (2000)</td>
<td>+6 dB</td>
<td>+5 dB</td>
<td>+1 dB</td>
<td>-8 dB</td>
</tr>
<tr>
<td></td>
<td>(+/-14)</td>
<td>(+/-14)</td>
<td>(+/-11)</td>
<td>(+/-12)</td>
</tr>
<tr>
<td>Lee (2008)</td>
<td>+5 dB</td>
<td>0 dB</td>
<td>-5 dB</td>
<td>-5 dB</td>
</tr>
<tr>
<td></td>
<td>(+/-5)</td>
<td>(+/-5)</td>
<td>(+/-8)</td>
<td>(+/-8)</td>
</tr>
<tr>
<td>Vander Werff et al (2009)</td>
<td>+13 dB</td>
<td>0 dB</td>
<td>-3 dB</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(+/-12)</td>
<td>(+/-9)</td>
<td>(+/-14)</td>
<td></td>
</tr>
</tbody>
</table>
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Chirp Stimuli in ABR Measurement: Now Available on Selected Clinical Devices

CE-Chirp®
Evidence-Based Clinical Applications of Chirp Evoked ABRs and ASSRs: “Early” Chirp Literature

- Elberling C (2010). A direct approach for the design of chirp stimuli used for the recording of auditory brainstem responses. *JASA, 128*, 2955-2964

NOTE: CE-Chirp refers to Danish scientist Claus Elberling (CE)

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**Cochlear Excitation Patterns for Click versus Narrow Band Stimulation**

- **Upward spread of excitation**
- **Downward spread of excitation**

*Continuous, narrow band stimuli*

*Transient, broad band stimuli*
Chirp Temporal Waveform

Temporal Compensation via Input Compensation
(Courtesy of Claus Elberling)
peRET SPLs:
CE-Chirp Octave Bands vs. Tone Bursts

- ISO 389-6: 2-1-2 Tone Burst peRET SPLs (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

Courtesy of East Carolina University

**ABR Latency Values: CE-Chirp Octave Bands**

CE-Chirp octave bands are derived from CE click chirps where low frequencies are presented before high frequencies. Therefore, wave V latencies for low frequency octave bands (e.g. 500 Hz) appear earlier than the high frequency octave bands (e.g. 1000, 2000, or 4000 Hz)

![ABR Latency Values Diagram](chart6.png)
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![Figure 6. Grand Average ABR waveforms from N = 20 ears. The Grand Averages are obtained by time-shifting the underlying individual waveforms according the wave V latency. The thin line in the LS-Chrip 40 dB nHL condition shows a small part (corresponding to wave I) of the Grand Average obtained by using the latency of wave I instead of wave V for the temporal adjustment.](image)

**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
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

2000 Hz Chirp Evoked ABR
*Stimulus rate = 37.7/sec*
*Total sweeps = 2318 ; Total test time = 61 seconds*

80 dB nHL
722 sweeps

35 dB nHL
570 sweeps

25 dB nHL
456 sweeps

20 dB nHL
570 sweeps
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

Electrophysiologic Estimation of the Audiogram:
One year 4 month boy
Advantages of CE-Chirp Stimulation of the Auditory Brainstem Response (ABR):
Advantages of Chirp Stimulation

- ABR amplitude is up to two times larger for chirp stimulation
- Larger amplitude contributes to:
  - More confident identification of wave V
  - Shorter test time is needed to identify wave V
  - Reduced test time for each stimulus frequency permits
    - More complete estimation of auditory threshold in speech frequency region
    - Possibility of infant ABR assessment in natural sleep without the need for sedation or anesthesia
  - More accurate thresholds are sometimes possible with chirp stimulation

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Evidence-Based Clinical Applications of Chirp Evoked ABRs and ASSRs:
Selected Recent Literature (N = > 45 articles via PubMed)


Evidence-Based Clinical Applications of Chirp Evoked ABRs and ASSRs

- Enhanced diagnostic assessment with ABRs elicited with CE-chirp air conduction click stimuli
  - Larger amplitude of wave III and wave V
  - Larger amplitude of wave I
- Faster estimation of frequency-specific air-conduction ABR and ASSR thresholds
  - Up to 50% reduction in overall test time
  - Detection of an ASSR in 10 – 15 seconds with fast rate
- Better detection of ABR and ASSR with low frequency stimuli
- More confident detection of bone conduction ABR
- Intra-operative monitoring with response detection in less time
Resource

- eHandbook of Auditory Evoked Responses (2015)

- Procedures and protocols for recording ECochG, ABR, ASSR, AMLR, ALR, and P300