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Improving EHDI with CAEPs:
Clinical Assessment of the Cortical Auditory Evoked Potential in Children with Hearing Loss

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Disclosure

The HEARLab system was donated to Hearts for Hearing by Frye Electronics as part of an ongoing research project.

Learner Outcomes

As a result of this course, participants will be able to...

- List characteristics of a CAEP: P1-N1-P2 complex.
- Identify at least three populations for whom CAEP testing can assist in developing a plan of care.
- Make clinical management suggestions based on presence or absence of CAEPs
Agenda

- Early Hearing Detection and Intervention (EHDI)
- Cortical auditory evoked potentials (CAEPs)
  - Overview of the $P_1-N_1-P_2$ complex
  - Obtaining the measurement
  - Interpreting the measurement and developing a plan
  - Current literature regarding reliability
- Using CAEPs to make intervention recommendations
- Case studies from Hearts for Hearing

Outcomes of Early- and Late-Identified Children at 3 Years of Age: Findings From a Prospective Population-Based Study

Beginning at 6 months old, every 6 month delay in implantation resulted in a $\frac{1}{2}$ standard deviation decrease in language outcomes.
The “Black Hole” in Pediatric Audiology

- ABR
- Reliable Behavioral Audiometry
- Hearing Aid Fitting
- Reports from Parents and Auditory Verbal Therapist
- Assessments of Functional Auditory Performance
  - LittlEARS
  - PEACH
- Cortical Auditory Evoked Potentials (CAEPs): P₁-N₁-P₂ complex
CAEPs: $P_1$-N$_1$-$P_2$ Complex

- Complex can be elicited via click, tone burst, or speech stimuli
- Response occurs at 50-300 ms post-stimulus onset
- $P_1$ is generated by the primary auditory cortex
- $P_1$ is robust in children and $N_1$ and $P_2$ will develop at approximately seven years old

![CAEPs waveform](image)

Advantages of Speech-Evoked CAEPs

- Acoustics of speech stimuli are similar to the sounds the child will hear in daily life and are handled well by hearing aid signal processing
- CAEPs evaluate the integrity of the auditory pathway to the level of the auditory cortex; assesses detection, not discrimination
- CAEPs can be present in some children with auditory neuropathy spectrum disorder (ANSD)
- CAEPs can be recorded in awake infants when signals are presented at suprathreshold levels; responses are patient state dependent and “can be modified by auditory training.”

[References: Burkard et al., 2007, Punch et al., 2015]
Advantages of Speech-Evoked CAEPs

- Clinician
  - Provides additional information regarding auditory function
  - Identifies fittings that may need adjustments
  - Assists in the determination of optimal intervention
    - Hearing aid
    - Frequency-lower technology
    - Cochlear implant
- Family
  - Present aided CAEP provides reassurance that the child has access with current technology
  - Absent CAEP reinforces the need for consistent device use or the need to discuss further intervention

Why aren’t CAEPs routinely used in the clinic?

- Previously, CAEP measurements for research studies were completed with expensive, multi-channel equipment
- Clinicians may not feel comfortable analyzing CAEP waveforms
  - Morphology and latency of the waveform changes as a function of age and auditory exposure
- Clinicians may not feel comfortable calibrating CAEP systems, particularly for soundfield assessment
- Clinicians may not have access to appropriate CAEP stimuli
  - Tonal signals may produce artifact when processed by digital hearing aids
  - Many clinicians do not have the resources to generate speech signals
Previously, CAEP measurements for research studies were completed with expensive, multi-channel equipment. Clinicians may not feel comfortable analyzing CAEP waveforms. Clinicians may not feel comfortable calibrating CAEP systems, particularly for soundfield assessment. Clinicians may not have access to appropriate CAEP stimuli.

- The Gnd (ground) electrode is to be attached on the forehead.
- The Ref (reference) electrode is to be attached to the left or right mastoid.
- The Cz (active) electrode is to be attached to the vertex position.

Advantages of the HEARLab System:

- Allows for acquisition of CAEP with clinically-conducive single-channel recording.
- Automatic response detection via statistical analysis and calculation of residual noise.
- Simple procedure to calibrate stimuli for soundfield delivery.
- Includes calibrated speech signals:
  - /m/ 500 Hz
  - /g/ 1250 Hz
  - /t/ 4000 Hz
  - /s/ 6-8000 Hz
Prepping for CAEP Testing

Obtaining CAEPs
Interpreting CAEPs and Developing a Plan

<table>
<thead>
<tr>
<th>CAEP</th>
<th>Approximate Behavioral Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present at 55 dB SPL</td>
<td>No greater than mild hearing loss</td>
</tr>
<tr>
<td>Present at 65 dB SPL</td>
<td>Mild to moderate hearing loss</td>
</tr>
<tr>
<td>Present at 75 dB SPL</td>
<td>Moderate to severe hearing loss</td>
</tr>
<tr>
<td>Absent at 75 dB SPL</td>
<td>At least severe hearing loss</td>
</tr>
</tbody>
</table>

Why might a CAEP be absent?

- High levels of noise in the recording
- Varying levels of alertness of the child
- Severe cases of auditory neuropathy spectrum disorder
- Future poor speech discrimination
- Cortex maturation
- Skull morphology and/or thickness of the cortical folds
- Stimulus is not audible
- Unknown reasons
- Measured aided CAEPs
  - 18 infants with bilateral sensorineural HL
  - Mean age 6.7 months (SD 2.3)

- Estimated audibility was determined via VRA thresholds obtained at a later date

- Aided CAEPs were present in approximately 70% of infants with SNHL when the signal was presented at a positive sensation level

- Measured aided CAEPs
  - 25 infants with sensorineural HL
  - Mean age 19 months (SD 8)

- Estimated audibility was determined via VRA thresholds obtained at a later date

- Aided CAEPs were present in approximately 80% of infants with SNHL when the signal was presented at a positive sensation level
• Measured aided CAEPs
  • 29 infants with sensorineural HL
    • Mean age 6.6 months (SD 2.9)
  • 17 infants with auditory neuropathy
    • Mean age 11.2 months (SD 8.5)

• Measured behavioral thresholds via VRA

• CAEPs as a function of sensation level:
  • SNHL: present in approximately 70%
  • ANSD: present in approximately 80%

• 104 infants with normal hearing
  • Age range: 5-29 weeks

• Evaluated the following:
  • Presence of CAEP
    • All infants had a CAEP to at least one, and many two, stimuli
  • Ability to complete testing
    • Testing was completed 95% of the time
  • Duration required to complete testing
    • Average test duration was 27 minutes
      • 13 minutes prep and 13 minutes acquisition
  • Clinicians’ and parents’ perception
    • Parents reported all aspects of the test acceptable
    • Interviews revealed a positive experience
CAEP Clinic at Hearts for Hearing

- Auditory Neuropathy Spectrum Disorder (ANSD)
  - All children diagnosed with ANSD are seen for unaided CAEP testing to determine need for amplification and estimated behavioral thresholds.

- Cochlear implant track
  - Children moving toward implantation for whom reliable behavioral testing cannot be obtained are seen for aided CAEP testing to evaluate aided benefit with current hearing technology.

- Slight or mild sensorineural hearing loss
  - All children diagnosed with slight or mild sensorineural hearing loss are seen for unaided CAEP testing to determine need for amplification.

- Hearing aid check (<9 months old or developmentally delayed)
  - All babies fit with hearing aids are seen for aided CAEP testing to evaluate aided benefit with hearing technology.

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CAEP Clinic at Hearts for Hearing

- Total patients tested: 165
  - 22 could not be completed due to excessive artifact (13%)

- Sensorineural or Mixed HL: 52 (32%)
  - Bilateral: 41
  - Unilateral: 11

- Auditory Neuropathy: 68 (41%)
  - Bilateral: 52
  - Unilateral: 16

- Normal Hearing: 23 (14%)

- Total Patients Reliably Tested: 143
  - 126 of the patients tested had a CAEP to at least one stimulus (88%)
JM was referred to H4H due to referring on her NBHS in both ears.

April 2014 – 5 months old, born at 25 weeks gestation, 143 day NICU stay, no family history of hearing loss

**ABR testing confirmed bilateral ANSD**

CASE STUDY #1

JM was followed at H4H for bilateral ANSD; no amplification.

August 2014 – 9 months old, parents denied concerns regarding auditory awareness

October 2015 – 1.10 year old, parents denied concerns regarding auditory awareness

November 2015 – binaural hearing aid trial initiated
CASE STUDY #1

JM was followed at H4H for bilateral ANSD; bilateral hearing aids.

June 2016 – 2.7 years old, parents reported little-to-no aided benefit

August 2016 – 2.9 years old, parents reported little-to-no aided benefit

CASE STUDY #1

JM was followed at H4H for bilateral ANSD; bilateral cochlear implants.

September 2016 – 2.10 years old, simultaneous bilateral cochlear implantation

- 1 week post-op activation
- Parents reported immediate improvement in auditory awareness

February 2017 – 3.3 years old, parents and auditory-verbal therapist report continued improvement in awareness and speech and language development
CASE STUDY #1

JM was followed at H4H for bilateral ANSD; bilateral cochlear implants.

March 2017 – 3.4 years old, five months post-cochlear implant activation

January 2018 – 4.2 years old

LNT words at 60 dBA

Right CI: 88%

Left CI: 92%

CASE STUDY #2

AS was referred to H4H due to referring on her NBHS in the left ear.

June 2016 – 2 weeks old, born full-term, no NICU stay, no family history of hearing loss
CASE STUDY #2

AS was referred to H4H due to referring on her NBHS in the left ear.

July 2016 – 2 months old, parents reported some concerns regarding auditory awareness

January 2017 – 7 months old, parents reported improvement in auditory awareness

<table>
<thead>
<tr>
<th>SPL</th>
<th>/m/</th>
<th>/n/</th>
<th>Left ear, right ear masked /n/</th>
</tr>
</thead>
<tbody>
<tr>
<td>65 dB SPL</td>
<td>0.001</td>
<td>0.039</td>
<td></td>
</tr>
<tr>
<td>55 dB SPL</td>
<td>0.025</td>
<td>0.079</td>
<td>0.038</td>
</tr>
</tbody>
</table>
CASE STUDY #3

EP was referred to H4H due caregiver concern for hearing loss.

August 2016 – 9 months old, born full-term, suspected stroke in utero, 5 day NICU stay, passed NBHS in both ears

November 2016 – caregiver concerns persist for lack of awareness to sound and limited speech and language progress

- Tympanometry – Type A, good movement, bilaterally
- Distortion Product Otoacoustic Emissions – present bilaterally
- Cortical Auditory Evoked Potentials – present at 65 dB SPL to /m/, /t/, and /g/
CASE STUDY #4

MP was referred to H4H due to speech and language concerns.

December 2014 – 2.7 years old, passed newborn hearing screening, no family history of hearing loss

March 2015 – bilateral hearing loss confirmed via sleep-deprived ABR and behavioral audiometry

MP was followed at H4H for bilateral SNHL; bilateral hearing aids.

December 2015 – 3.7 years old
June 2016 – 4.1 years old
CASE STUDY #4

MP was followed at H4H for bilateral SNHL; bilateral hearing aids.

April 2017 – 4.10 years old,
Phonak Soundrecover2 technology

January 2018 – 5.7 years old, PBK words at 60 dBA
Right HA: 100% (quiet) 76% (+10 SNR)
Left HA: 92% (quiet) 72% (+10 SNR)
Binaural HAs: 96% (quiet)

Recap: Clinical Applications for CAEPs

- Provides additional information regarding auditory function for individuals with sensorineural hearing loss and auditory neuropathy spectrum disorder
- Identifies patients that may need adjustments and/or a change in intervention
  - Hearing aid
  - Frequency-lower technology
  - Cochlear implant
- Comparing unaided and aided CAEPs may reinforce to a family the need for consistent device use

Recap: Clinical Applications for CAEPs

- CAEP testing should be completed with multiple stimuli and at multiple presentation levels
  - Absent responses in all conditions enhance the likelihood of stimulus inaudibility

- CAEP testing and intervention should been conducted in conjunction with other assessments
  - LittIEARS
  - PEACH
  - Behavioral audiometry
  - Parent and therapist input

References


