Recommendations for Measuring the Electrically-Evoked Compound Action Potential in Children with Cochlear Nerve Deficiency

Shuman He, MD., PhD
July 12, 2019
Acknowledgements

• This work was supported by the R03 (R03DC013153) and the R01 grant (R01DC017846) grant from NIH/NIDCD.

• Drs. Michelle Shannon and Cynthia Warner from Nationwide Children’s Hospital

• Drs. Kevin D. Brown and Lisa R. Park from The University of North Carolina at Chapel Hill.

• Dr. Holly F.B. Teagle from University of Auckland.

• Drs. Xiuhua Chao, Jianfen Luo, Lei Xu and Ruijie Wang from Shandong ENT hospital.
Why?

• Around 50 – 60% of children with CND have other neurological deficits in addition to hearing loss that limit the child’s ability to provide reliable behavioral responses, which makes cochlear implant clinical management extremely challenging.

• In the absence of reliable behavioral responses, electrophysiological measures like the electrically evoked compound action potential (eCAP) are useful tools for clinicians due to their objective nature.

• Measuring the eCAP in children with CND is difficult due to electrical artifact contamination.
Default Parameters for Measuring the eCAP

<table>
<thead>
<tr>
<th>Probe</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probe Active Electrode</td>
<td>9</td>
</tr>
<tr>
<td>Probe Indifferent Electrode</td>
<td>MP1</td>
</tr>
<tr>
<td>Probe Current Level</td>
<td>130</td>
</tr>
<tr>
<td>Probe Pulse Width [us]</td>
<td>25</td>
</tr>
<tr>
<td>Probe Rate [Hz]</td>
<td>80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recording</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recording Active Electrode</td>
<td>11</td>
</tr>
<tr>
<td>Recording Indifferent Electrode</td>
<td>MP2</td>
</tr>
<tr>
<td>Gain [dB]</td>
<td>50</td>
</tr>
<tr>
<td>Delay [us]</td>
<td>122</td>
</tr>
<tr>
<td>Artefact Cancellation Technique</td>
<td>Forward M</td>
</tr>
<tr>
<td>Artefact Reduction</td>
<td>Off</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Masker</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masker Active Electrode</td>
<td>9</td>
</tr>
<tr>
<td>Masker Indifferent Electrode</td>
<td>MP1</td>
</tr>
<tr>
<td>Masker Current Level</td>
<td>130</td>
</tr>
<tr>
<td>Masker Pulse Width [us]</td>
<td>25</td>
</tr>
<tr>
<td>Number of Maskers</td>
<td>1</td>
</tr>
<tr>
<td>Masker Rate [Hz]</td>
<td>100</td>
</tr>
<tr>
<td>Masker Probe Interval [us]</td>
<td>400</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Averaging</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Sweeps</td>
<td>50</td>
</tr>
<tr>
<td>Measurement Window [us]</td>
<td>1600</td>
</tr>
<tr>
<td>Effective Sample Rate [kHz]</td>
<td>20</td>
</tr>
</tbody>
</table>
Typical Traces Recorded using Default Parameters in Children with CND

**Default parameters (25 μs/phase)**

- CND1
- e1@222
- e2@228
- e6@228
- e7@228
- e11@210
- e12@216
- e16@222
- e17@222
- e21@216
- e22@210

**Parameters with increase PPDs (50 or 75 μs/phase)**

- CND1
- e1@200
- e2@200
- e6@206
- e7@208
- e11@200
- e12@200
- e16@200
- e17@200
- e21@200
- e22@200

100 400 700 1000 1300 1600 1900

Time (μs)

(a)
Children with CND have Poorer Neural Survival at the Apex than the Base
The CN in Children with CND has prolonged absolute refractory recovery time.
The CN in Children with CND has prolonged absolute refractory recovery time

- Children with CND had longer $t_0$ than children with normal-size CNs.
Optimized Parameters for Measuring the eCAP

**Probe**
- Probe Active Electrode: 9
- Probe Indifferent Electrode: MP1
- Probe Current Level: 150
- Probe Pulse Width [μs]: 50
- Probe Rate [Hz]: 15

**Recording**
- Recording Active Electrode: 7
- Recording Indifferent Electrode: MP2
- Gain [dB]: 40
- Delay [μs]: 122
- Artefact Cancellation Technique: Forward
- Artefact Reduction: Off

**Masker**
- Masker Active Electrode: 9
- Masker Indifferent Electrode: MP1
- Masker Current Level: 160
- Masker Pulse Width [μs]: 50
- Number of Maskers: 1
- Masker Rate [Hz]: 100
- Masker Probe Interval [μs]: 400

**Averaging**
- Number of Sweeps: 100
- Measurement Window [μs]: 1600
- Effective Sample Rate [kHz]: 20
Traces Recorded using Different Parameters in CND1

(a) Default parameters (25 μs/phase)

(b) Parameters with increase PPDs (50 or 75 μs/phase)

(c) Optimized parameters (50 or 75 μs/phase)
Traces Recorded using Different Parameters in CND2
Results:

- Using the default parameters, the eCAP was recorded at 92 out of 245 (37.50%) electrodes tested.
- Using the recommended parameters, the eCAP was recorded at 407 out of 468 (86.97%) electrodes tested.
Conclusions

• This recommended method can be used to measure the eCAP in children with CND in clinical settings.

• Successfully measuring the eCAP in individual patients requires adjusting and optimizing many stimulating and recording parameters.

• Results of eCAP responses measured using this recommended method may provide limited, yet useful information for making clinical decisions in programming parameter selection for this unique patient population.
Thank you!