Concurrent Recording of the Electrically Evoked Compound Action Potential and Auditory Brainstem Response in Cochlear Implant Users

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BACKGROUND

Purpose and Technological Feasibility

- In the ABR waveform, W_I reflects activity in the 8th cranial nerve while W_V reflects activity in the upper brainstem. The amplitude ratio between W_I and W_V is emerging as an important metric for auditory function.
- In the electrically evoked ABR (eABR), eW_I cannot be measured because of artifact associated with cochlear implant (CI) stimulation. The electrical eW_I /eW_V ratio therefore cannot be measured in a single test as the W_I /W_V ratio can for an acoustically evoked ABR.
- For MED-EL Corporation CIs, the electrically evoked compound action potential (eCAP), equivalent to eW_I, is measured with the Auditory nerve Response Telemetry (ART) test. The ART uses sequences of 'masker' and 'probe' biphasic pulses to extract an eCAP (see Fig. 1). Note that the ART also generates an external trigger.

Clinical/Translational Importance

- In acoustic hearing, the W_I /W_V ratio is of interest in areas such as cochlear synaptopathy and central gain theory.
- Cochlear synaptopathy refers to the disruption of synapses between the inner hair cells and the auditory nerve from minimal noise exposure, resulting in a reduction of functional auditory nerve fibers (Kukawa & Liberman, 2009). Questions remain about age-related effects and tonotopic remain about place of stimulation.

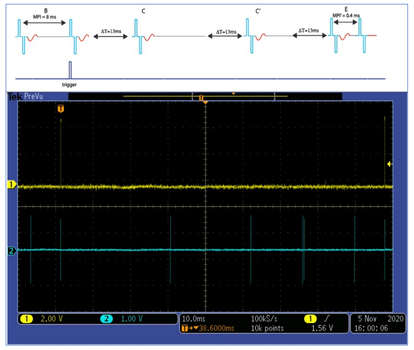

Figure 1: Schematic of biphasic pulse sequence consisting of four segments B, C, C', and E, as defined by Miller et al. (2000). A single eCAP free of artifact contamination can be extracted by the computation B-C-E+C'.

- Central gain theory refers to compensatory mechanisms at higher auditory centers in response to reduced input at the periphery (Schaette & McAlpine, 2011).
- These areas are also applicable to electric hearing, but the derivation of the eW_I /eW_V currently requires a 2-step process (eCAP plus eABR), making testing inefficient.
- If a simultaneous eW_I /eW_V response can be obtained successfully in a single test, this would increase the efficiency with which questions related to age and tonotopic place of stimulation can be applied to electric hearing.

OBJECTIVES

- Can the ART test be used to simultaneously generate an eABR using an external trigger and therefore concurrently measure the eCAP (equivalent of eW_I) and eW_V in a single test? This would allow the eW_I/eW_V ratio to be derived from a ***single*** test.
- Is the eW_I/eW_V ratio age-dependent and does it depend on cochlear place of stimulation along the electrode array?

METHODS

Participants

- 5 MED-EL CI users (see Table 1) ranging in age from 25 to 71 years (M= 55.2, SD=18.8).
- All provided consent for the study procedures approved by the Biomedical Institutional Review Board at the University of North Carolina, Chapel Hill.

Loudness Scaling

- Loudness scaling was completed on basal, medial, and apical electrode pairs.
- The goal was to identify a comfortable stimulation level between medium and loud that also generated a clear eCAP.

eCAP/eABR Concurrent Recordings

- Participants were prepped using a single-channel electrode montage (See Fig. 2)
- Stimuli for the concurrent recording were generated using the ART Advanced Setup module in the MED-EL MAESTRO software. The eCAP responses were recorded using the software's proprietary algorithm.
- The eABR was simultaneously recorded using an IHS Smart EP platform synchronized to the ART via its external trigger. Parameter settings on the IHS were selected such that only the eABR evoked by the stimulus pulse in Segment B was averaged (see Fig. 1).
- To confirm the eABR results generated by the ART stimulus sequence, separate eABR tracings were also completed using the MAESTRO eABR module. eABR tracings were collected using a stimulus rate of 11.1 Hz, which is similar to the rate of the concurrent eCAP/eABR recording parameters.
- All eCAP and eABR waveforms were exported to Excel for analysis

RESULTS

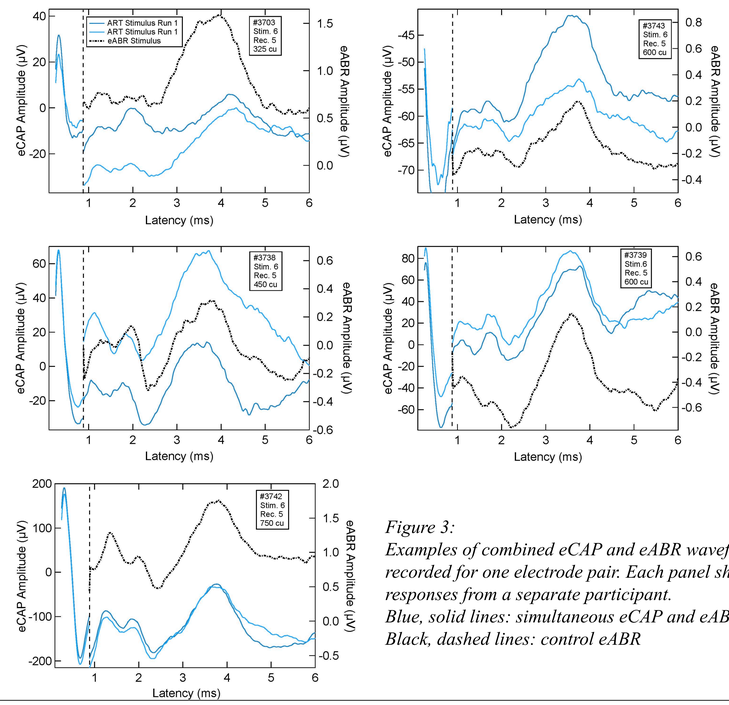

Figure 3:
Examples of combined eCAP and eABR waveforms recorded for one electrode pair. Each panel shows responses from a separate participant.
Blue, solid lines: simultaneous eCAP and eABR
Black, dashed lines: control eABR

Participant	Sex	Age (years)	Etiology	Electrode Array	Duration of Deafness (years)	Duration of Device Use (years)
3703	Female	25	Unknown, congenital	Mi10xx Series, Standard	17	8
3738	Female	70	Viral Etiology, progressive	Mi12xx Series, FLEXsoft, EAS off	30	3
3739	Male	71	Meniere's Disease & labyrinthectomy	Mi12xx Series, Standard, EAS off	20	5
3742	Male	59	Meniere's Disease progressive, asymmetric hearing loss	Mi12xx Series, Synchrony 2, FLEXsoft	4	1
3743	Female	51	Sudden SNHL	Mi12xx Series, FLEXsoft	0.60	2

Table 1: Participant Demographics

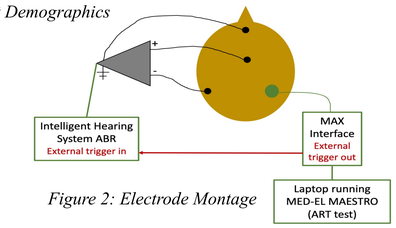

Figure 2: Electrode Montage

DISCUSSION AND CONCLUSION

- Can the ART test be used to simultaneously generate an eABR using an external trigger and therefore concurrently measure the eCAP (equivalent of eWI) and eWV in a single test?
  - **Yes - feasibility has been established!**
- Is the eW_I/eW_V ratio dependent on cochlear place of stimulation along the electrode array and participant age?
  - **In-progress.**
- Recruitment is ongoing to establish a larger cohort of test subjects with a wide age range.
- Having established feasibility, a larger-scale investigation is necessary to establish normative values for the eW_I/eW_V ratio as a function of electrode position in young adult listeners.
- After these baseline values have been established, the effects of aging and site of cochlear stimulation can be evaluated for possible age-dependent reductions in the eW_I/eW_V.

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