INNOVATION IN OBJECTIVE AUDITORY TESTING: ELECTRICALLY EVOKED AUDITORY POTENTIALS

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OBJECTIVE MEASURES

▪ Electrically evoked stapedial reflex,

▪ Electrically evoked auditory nerve compound action potential – Neural Response Telemetry (NRT),

▪ Electrically evoked brain stem responses (eABR),

▪ Electrically evoked potentials of auditory cortex (eAEP)
NEURAL RESPONSE TELEMETRY (NRT)
Neural Response Telemetry

Each electrode stimulates different populations of neurons. From histological data revealed in animals with experimentally induced deafness and data obtained from human temporal bones it is possible to conclude that degeneration of spiral ganglion neurons and their peripheral axons differs along the cochlear partition.
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Assuming that eCAP parameters reflect parameters of stimulating neuronal populations it is possible to conclude that responses will vary not only between patients but according the place of stimulation as well.
Based on our results it was concluded that NRT could be used for psychophysical levels as well as speech processor individual stimulation map estimation.

This is particularly important when constructing individual speech processor mapping based on the NRT data in small children and patients with multiple malformations.
NRT – excitation summation

Levels close to MCL

Sub-threshold levels $St = M$
NRT – recovery function

- Auditory nerve fibres refractory period
- Could be used for the diagnosis of some forms of neuropathies (increased AN refractory period time)

The correlation between the AN refractoriness parameters and patients individual stimulation frequency preferences (for experienced CI users) was obtained.
NRT – spread of excitation
NRT – spread of excitation

Masker and probe completely overlap

Masker and probe partially overlap

Masker and probe do not overlap
NRT – spread of excitation


Spread of excitation is significantly narrower in case of perimodiolar electrode which could suggest better differentiation (discrimination) with this location.

The significant decrease of stimulation threshold level was also obtained.
Cochlear® CR120/220

- Handheld & wireless
- Conducts
  - AutoNRT
  - Impedance
- CR 120/220 requires
  - Sound Processor
- Gives instant results for
  - Electrode integrity
  - ECAP thresholds (t-NRT)
eABR
EABR PROBLEMS

1. eABR distortion by the electrical stimulus artifact contamination

2. Difference in the stimulus presentation rate during EABR registration (low-pulse-rate) and conventional psychophysical threshold estimation (high-pulse-rate) in cochlear implant patients.
New original method of eABR registration with the use of simultaneous masking paradigm was developed.
eABR

• Threshold and growth of response (wave V) with level
• Refractory recovery
• Binaural interaction component
• Use of eABR latency to assess longitudinal changes in neural responsiveness to electrical stimulation (significant decrease in wave III and wave V latencies within the first year of device use for a group of pre-lingually deafened children)
eABR - Binaural Interaction Component (BIC)

Gordon et al (2007, 2008) used the BIC response to assess auditory brainstem Development in children who were bilaterally implanted either simultaneously with a short time interval between ears (<1 year), or with a longer time interval between ears. Results showed prolonged eABR and BIC latencies for the later-implanted ear for both groups of children implanted in sequential surgeries. Within the first 9 months of bilateral implant use latencies for the short-delay group were similar to those for the simultaneous group.
eABR

Speech processor adjustment

1. estimation of behavioural threshold, comfortable and threshold levels of stimulation (based on eABR data) for stimulus presentation rate used for the eABR recording;

2. extrapolation of the data obtained to the conventional stimulus presentation rate
Combined registration of the peripheral (eCAP) and central parts (eABR) of the auditory system
• Results of express NRI and presence/absence of eABR were compared with results of rehabilitation: behavioral thresholds and phoneme perception
Cortical auditory evoked potentials (CAEPs) are brain responses that are evoked by sound and processed in or near the auditory cortex. The responses must be recorded when the subject is awake.
MATURATION OF CAEPS WITH AGE
AN IMPORTANT DISTINCTION

We are not trying to verify hearing aid fitting or CI adjustment by measuring aided thresholds using evoked potentials.

We are trying to validate the hearing aid fitting or CI effectiveness by showing that speech stimuli across the speech spectrum evoke a neural response at the level of the auditory cortex and therefore are likely to be perceived by the infant.
Grand average adult (N=14) CAEP for the eight tonal and speech stimuli, recorded at Cz.
500 Hz = orange, 1 kHz = dark pink,
2 kHz = light pink, 4 kHz = red,
/k/ = aqua /t/ = dark blue,
/d/ = dark green, /g/ = light green.
CAEPs TO DIFFERENT STIMULI

- /t/ black
- /g/ blue
- /m/ green
- 500 Hz red
- 2 kHz pink
SUMMARY

Cortical responses are present in most aided infants and children with moderate-to-profound hearing loss.

Different stimuli often lead to different response shapes within individual hearing impaired children.

Aided responses are consistent with and sensitive to changes in CI fitting parameters in many implanted children.
Child’s brain plasticity decreases and becomes less adaptive to new acoustical input in the age of 3-4 years

CROSS-MODAL REORGANIZATION AFTER CI (optical and somatosensory) which is followed by additional activation of temporal lobe

Dorman et al 2009
$P_1$ latency as function of the chronological age of children with CI
CAEP DYNAMICS IN CHILDREN WITH CI

Early implantation

Late implantation
CAEP DYNAMICS IN CHILDREN WITH CI
INTERNATIONAL CLINICAL TRIALS

HearLab® System

(Australia)
NAL-ACA Stimuli

Three speech sounds: /m/ /g/ /t/

Aided Cortical Assessment
- Free field presentation
- Speech sounds
- Can be tested aided or unaided
- Focused on infants

/M/ 250 Hz
/G/ 1250 Hz
/T/ 3250 Hz
Demographics

- 87 Cochlear Implant user
  - 65 Cochlear Nucleus
  - 22 Advanced Bionics
- 11 Adult
- 76 Children
  - Age: 3 – 137 (mean: 6.7)
  - CI Experience: 2 – 9 years (mean: 5.8 y)
Case Report I

- Adult, Female, age 33
- Cochlear Nucleus since 3 y
- 80% word score @ 65 dB (polysyllables in quite)
- Good correlation between results

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Were responses detected?

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<th>55 dB SPL</th>
<th>/m/</th>
<th>/n/</th>
<th>/s/</th>
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Averaged Responses at 55 dB SPL

Legend:
- /m/  
- /n/  
- /s/  

View history...  View p-values
Case Report II

- Child, male, age: 13
- Cochlear Nucleus since 2 y
- Good correlation of results (no response at LF)

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Were responses detected?

- 55 dB SPL
  - /m/:
  - /t/:
  - /q/:
  - /s/:

Averaged Responses at 55 dB SPL
Case Report III

- Adult, Female, age 33
- Cochlear Nucleus since 6 months
- 80% word score @ 65 dB (polysyllables in quite)
- Some uncertainties @ 65 dB ACA
- Optimization of parameter or retest
Age – 21
CI – 2010
Progressive hearing loss since 4yrs
Age – 11
CI – 2006
Progressive hearing loss since 1 year
Age – 18
CI – 2010
Progressive hearing loss since 3 yrs
eCAEP

• Longer deafness period and late CI are accompanied by eCAEP immaturity and leaks longer latencies

• eCAEP could be used for the quality of HA amplification before CI or for the estimation of auditory cortex development after CI

• Changes in the eCAEP morphology could be followed by worse speech discrimination
ACC is essentially a second N1-P2 complex that occurs in response to a change in a longer-duration continuous stimulus.
eACC

- eACC is based on cortical detection of spectral, temporal or amplitude changes in the stimulus.
- It may have clinical utility as an objective indication that a difference in the stimulus was detected by the central auditory system.
- eACC represents the detection of a stimulus change at the level of the auditory complex, which is a prerequisite to discrimination.
Results showed that the magnitude of the eACC increased with the spatial separation between the two stimulated electrodes, consistent with larger pitch differences that may have been perceived between these electrodes.
eMMN is a difference waveform derived from a change in the P1-N1-P2 complex that occurs in response to a frequent (standard) versus infrequent (deviant) stimulus presented using “oddball” paradigm.
The response measured for the deviant stimulus typically presents as an enhanced N1 and/or reduced P2.

eMMN reflects the central auditory system’s ability to resolve differences in stimuli and therefore provides an objective measure of physiological mechanisms underlying auditory discrimination.

May have some utility in predicting speech perception ability.

In contrast to the eACC which is measured in response to sustained stimuli the eMMN is measured in response to repeated shorter duration stimuli and is quantified as a difference wave.

Significant negative correlation was shown between speech perception and eMMN latency and amplitude in a group of children with cochlear implants (better performance was found in individuals with shorter latencies and larger amplitudes).
eP300 consists of the P2-N2-P3 complex. Stimuli are presented using an oddball paradigm (as for the eMMN).
The primary difference between the eP300 and eCAEP, eACC and eMMN is that the P300 is an endogenous response that requires the listener to attend to the stimulus and actively participate in the task.

It involves auditory detection/differentiation mechanisms as well as cognitive processes.

Because the P300 reflects auditory attention and discrimination processes it can provide some indication of how speech is differentiated at the cortical level.

Significant correlation was shown between speech perception and eP300 latency and amplitude in a group of children with CI.
Cortical responses are useful for providing information about central auditory pathways, stimulus detection, perceptual discrimination and/or physiological maturation at higher levels of the auditory system.

One advantage that auditory cortical potentials have over more peripheral measures is that a wider range of stimuli can be used to elicit responses. The benefit is that it is possible to objectively evaluate the brain’s ability to detect or discriminate different stimulus characteristics such as loudness differences, temporal changes or speech tokens.

Longer duration of deafness and larger age at implant result in immature morphology and delayed eCAEP latencies.

Introduction of different classes of electrically evoked responses of auditory cortex will provide an objective control of rehabilitation effectiveness in children after cochlear implantation.