Transduction of a Complex Signal Through the Normal Cochlea and Through the Cochlear Implant

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Introduction & Reasoning

CI device → Brain → Audition

- Acoustic signals reaching CI → derived electrical Signal → stimulates the auditory system bypassing sensory receptors
- The ascending auditory system will reprocess the electrical signals generated by the CI.
- An assumed final outcome = signal detection, discrimination, recognition & comprehension.

Auditory Sensory Stimulation	Auditory electrical Stimulation
Auditory exposure	Auditory exposure
Auditory experience	Auditory experience
Auditory learning	Auditory learning

Auditory Sensory Stimulation

- Is initiated by a normal cochlea
- Is accomplished by an impaired cochlea through amplification

Auditory stimulation through cochlear implants

- Initiate auditory neural stimulation bypassing the auditory sensory system.
- Subsequently bypassing all cochlear active mechanisms: sensory afferent and sensory efferent controls as well as middle and external ears delay times.

Acoustic versus electrical stimulation

- Shift from the natural sequence of acoustic signal processing:
- External ear - middle ear - cochlear excitation patterns and sensory transduction → neural firings:

A derived electrical signal that directly excites the ganglia of the auditory nerve

What brain functions are linked to learning?

- Precision with which the brain processes phonological structure of spoken language.
- The neural signatures corresponding to timing and spectral variants in speech → neural encoding or representation
- Ability to pick speech in background noise (skill learned with time, improves with age)
- Central auditory processing abilities robust/ vulnerable/ poor to challenged listening.

Conclusions

- The growth function of the biological signal(cABR), measured by RMS amplitude, that parallels signal intensity may be an indication of:
  - **A.** Well Developed auditory pathway with increased neural density and consequently increased voltage capacity. This may reflect the importance of early stimulation and its organizing factors
  - **B.** Decreased RMS may indicate decreased surviving neural population which will influence the performance with the cochlear implant.
- The biological signal in cochlear implantees follows the acoustics of the signal and presents a heterogeneous latency shift which is less than norms due to absence of acoustic delay of external and middle ear transfer times and cochlear travelling wave.
- Variation of response reproducibility may reflect a low fidelity neural system affected by the etiology of hearing loss.

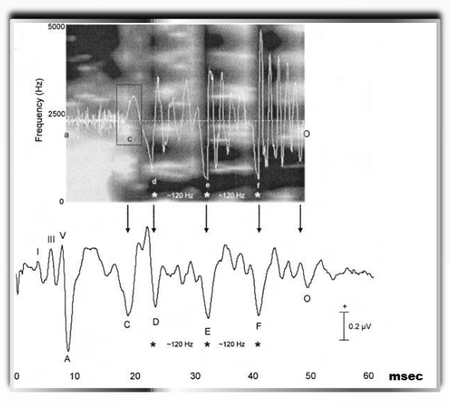
Study of CI transduction by speech ABR

The cABR a measure of CI transduction hypothesis

- Response correlation to speech stimulus reflects on:
  - **A.** Fidelity of CI processing of that signal.
  - **B.** Integrity and fidelity of brainstem processing.

The speech ABR (cABR)

- cABR is a tool to assess brainstem representation of a complex response.
- The stimulus is a CV syllable and consists of a transient consonant and a sustained vowel parts.
- The response consists of an onset respone (waves I, III and V) followed by the frequency following response.
- Normal cABR indicates normal brainstem encoding of a complex signal presented to the brain which will subsequently influence speech understanding and communication.



(Johnson et al., 2005)

- It Infers discrimination of spectro-temporal fluctuations in speech signal.
- It Infers discrimination of sounds with rapid acoustic transitions that are easily confused e.g stop consonants (momentary stop/ rapid release of airflow).

Methods and participants

Implantees

- n= 10, 5.6- 10.92 years old, 5 males and 5 females.
- Implanted with right Med-EL standard electrode array ,full insertion depth.
- Coding strategy (FS4 temporal weighting).
- Subjects with abnormal CT findings due to malformed cochlea or meningitis were excluded.

Norms

- n=2, 11 years old, males.
- Normal hearing age-matched controls.
- Normal click ABR responses.

- Speech syllable 40 msec /da/ was used to elicit speech ABR
- Stimulus delivered at a repetition rate of 2.1/sec with alternating polarity.
- Biologic navigator pro® and contralateral vertical electrode montage were used.
- A loudspeaker for CI monitored through Radioshack sound level meter at the subject's head and right TDH headphones for norms.
- Responses were online bandpass filtered by a 30-500 Hz. I/O Latency and RMS-intensity functions were done.
- Non-contrast multislice CT of the petrous bones was performed to affirm full electrode insertion depth.

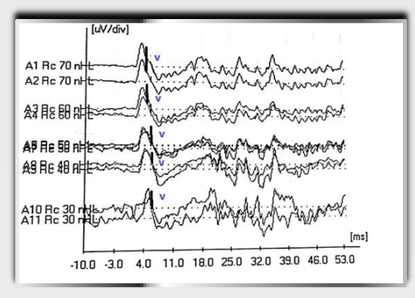
Acknowledgments

To cochlear implant unit, faculty of medicine, Alexandria university for providing the participants of the study

To Dr. Nina Kraus lab for providing the brainstem toolbox

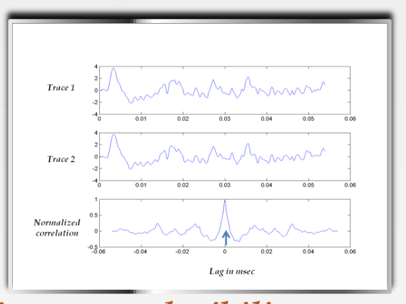
Results

cABR intensity I/O function /da/ syllable through loudspeaker for a CI patient



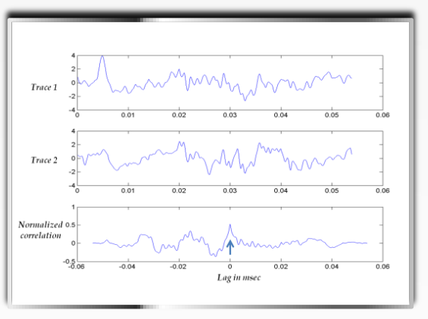
cABR Wave V latency: range 1.81 - 4.82 msec at 70 dBHL with a mean = 2.77± 1.06

cABR trace reproducibility at 70 dBHL

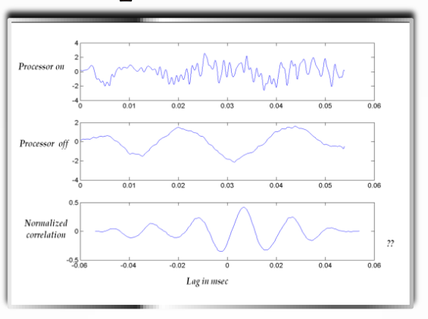


cABR Trace reproducibility: was maximal at moderate and high intensities (up to 99.65%) at 60 dB HL

cABR trace reproducibility at 30 dBHL



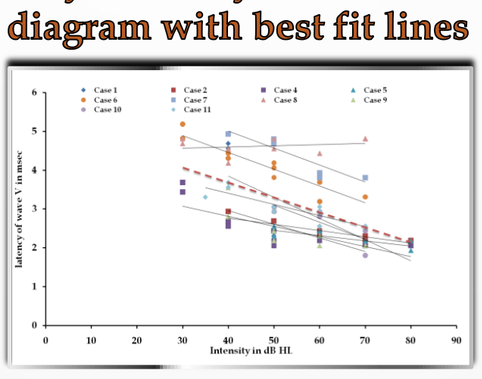
Correlating a trace at 60 dB HL with CI processor off



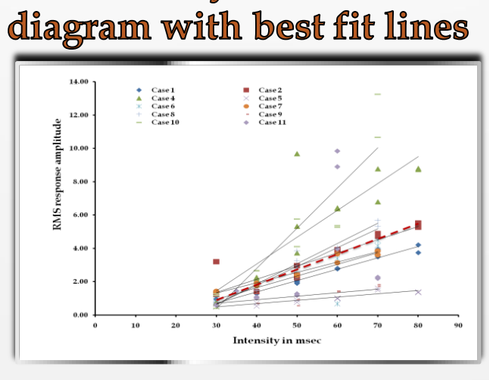
Criteria of trace repro

Lag between traces in msec: ideally= zero	Percentage correlation , ideally almost 100%
Study Lag range	Study trace correlation
- 18.875- 21.625 msec (threshold included)	17.64% - 99.65% (threshold included)
- 0.375 - 0.375 msec	31.58%- 99.65%

Latency-intensity function scatter diagram with best fit lines



RMS- intensity function scatter diagram with best fit lines



/da/- cABR correlation results

- cABR – stimulus /da/ correlation: range 4.55% -27.74% with a $\overline{X}$ = 16.62 ± 0.05
- cABR FFR– vowel correlation: range 14.22% -29.39% at 60 and 70 dB HL with a $\overline{X}$ = 19.90% ± 7.62%
- cABR FFR– vowel correlation in norms ranged from 20-30% at a delay range of 5.6 and 8.1 ms. (Cunningham et al., 2001)

Stenver View : Oblique Coronal Reconstruction showing full electrode insertion