ELECTRICAL AND SPEECH OUTCOME MEASURES FOR THE EVALUATION OF COCHLEAR IMPLANTEES: Preliminary Results

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Management of severe to profound sensorineural hearing loss requires comprehensive diagnostic and rehabilitative protocols such that the patient will develop adequate and satisfactory communication skills.

Outcome measures for patient performance gives a tool for assessment of the success of the rehabilitation strategies.
Because severe to profound sensorineural hearing loss shows wide variability of performance with the different rehabilitative approaches and since this category of hearing impairment is considered a criterion for candidacy to cochlear implants, thus outcome measures after cochlear implantation require integration of electrical tests that reflect the function of the surviving auditory nerve fibers.

In this respect, aided measurements, speech performance, and measurement of electrically evoked compound action potential of the auditory nerve, electrically evoked auditory brainstem responses and electrically evoked middle latency responses may provide a comprehensive evaluation for outcome measures of cochlear implantees.
Significant development in the field of cochlear implant electrophysiology has been accomplished by the presence of circuitry that uses bidirectional measurements by stimulation and response recording using the inserted electrodes.

Also provision of evoked potential systems allows harvesting of neural responses from the auditory pathway using stimuli generated by the speech processor programming software.

**Electrically Evoked Compound Action Potential: (ECAP)**

- ECAP is the synchronized response of peripheral auditory nerves to electric current pulses delivered by intra cochlear electrode. Bidirectional telemetry was incorporated in the design of the Nucleus CI24M and Clarion cochlear implant systems that permit recording of the ECAP.

- A stimulus is applied to a given intracochlear electrode and the resulting compound action potential is recorded from a neighboring electrode, amplified, and then encoded for transmission via the radiofrequency link back to the speech processor.

- A special software; Neural Response Telemetry (NRT) for Nucleus CI24M and Neural Response Imaging (NRI) for Clarion cochlear implants communicates with the speech processor to capture, process, store, and display the measurement data on a personal computer.
Wireless **bi-directional** communication of data between the programming system and the implant

![Diagram showing wireless communication between programming hardware and an implant](image)

- Commands
- Data

- Graph showing baseline corrected amplitude with P1 and N1 peaks.
- Peak P1 labeled with an arrow pointing to a value of 131 \( \mu \text{Volts} \).
Clinical application of NRT

- Programming of T- and C- levels of the speech processor MAP specially in uncooperative and multiply handicapped children.

- Intraoperative NRT in conjunction with electrode impedance data can help indicate the integrity of the implanted electrodes and the electrode nerve interface, confirming that the implant is functioning correctly.
**Electrically evoked auditory brainstem response (EABR):**

- It is the recording of electric potentials generated along the auditory pathway in response to electric stimulation of cochlear implant recipients using scalp electrodes.
- It has been studied in cochlear implant recipients for assessment of neural integrity, implant function, and spiral ganglion cell survival.
- It was found that mean EABR thresholds corresponds to a level that is two thirds the dynamic range in nucleus cochlear implant users. So, it was used to predict psychophysical measures for young children.

Firszt et al. (2002)
Electrically Evoked Middle Latency Responses (EMLR)

- The EMLRs may be preferred to EABR because they have longer latencies and thus are less likely to be contaminated by the stimulus artifact which occurs early in the response.

- Also, EMLR reflects the activation of a more significant portion of the auditory pathway than the EABR. Recordings in animals and humans indicate that it is a reliable response and may correlate with neural survival.

Firszt et al. (2002)
Since speech intelligibility is an important and a conventional outcome measure of the performance of cochlear implantees, the use of phonetic elements and other speech materials may be a more precise and less redundant tool in assessing auditory perception after cochlear implantation.

The relationship between electrical measures and auditory speech perception may provide an understanding of the outcome measure and may serve as a predictor in post implant prognosis for performance and planning of rehabilitative strategies.
The aim of the work is to:

- Evaluate ECAP, EABR and EMLR in cochlear implantees.
- Study the auditory perceived phonological element using the same MAP measurement in the electrophysiology.
- Correlate electrophysiology to auditory perception.
EXPERIMENTAL DESIGN

- Patients with severe to profound sensorineural hearing loss independent of age, sex and etiology of hearing loss who have received cochlear implants will be studied on condition that their implants possess features that will allow recording of ECAP and/or EABR.

- All multichannel cochlear implant recipients attending the rehabilitation program at the Audiology Unit, E.N.T Department, Alexandria University Hospital in the period from April 2005 to April 2007 will be asked to participate in this study.

- Subjects will attend initial and return visits where MAP creation will be done and tested against its electrophysiological counterpart.

- Speech perception testing will be done and scored to define the auditory perception pattern with the created MAP and the status of the residual functioning neural elements. Data will be analyzed statistically using appropriate tests.
**Psychophysical measures:**
- Psychophysical measures will be determined using Nucleus R126 software and the Portable Programming System (PPS) for Nucleus 24M cases and CI studio 2.02 and DIB for Medel C40+.

- Determination of the threshold (T-level) and the most comfortable level (C-level) will be achieved on all electrodes using different speech processing strategies.

- NRT based MAPs: T and C levels will be extrapolated from electrical recordings by setting C-levels 10 programming units above the NRT threshold and setting T-levels 20 programming units below the NRT threshold.
Measurement of the electrically evoked compound action potential:

- ECAP will be recorded using Neural Response Telemetry version 3.1
- Impedance of each electrode will be measured. Recording of NRT will be done using the forward masking paradigm.

Stimulus parameters:

- The stimulus is biphasic current pulses of 25μs duration with repetition rate of 80 Hz applied to every electrode in monopolar mode presented at LAPL and then decreased by 10 current units steps till a response appears, then stimulus current level will be increased by 5 current units steps till reaching the threshold T-NRT.

- In case of uncooperative children, the initial stimulus current level will be set at 150 current units and then increased by 10 current units steps till a response appears, then stimulus current level will be decreased by 5 current units steps till reaching the threshold T-NRT.
Recording parameters.
- Recording will be from an electrode which is 2 electrodes apical from the stimulating electrode unless there is high electrode impedance where recording will be from the nearest electrode.
- The amplifier gain and measurement delay will be optimized.
- The masker level will be set 10 current units higher than probe current level.
- The masker advance will be 500 µs.
- 100 sweeps will be averaged.
- Absolute latency and peak to peak amplitude of every recorded peak will be calculated.

Measurement of the electrically evoked auditory brainstem responses and electrically evoked middle latency responses:
- EABR and EMLR will be recorded using Neural Response Telemetry version 3.1 for stimulus generation for Nucleus 24M cases and Zebra version 3.0 for Medel C40+ cases and Smart Evoked Potential from Intelligent Hearing Systems (I.H.S) for recording and analysis of the response.
Stimulus parameters:

- The stimulus used to evoke EABR and EMLR will be biphasic current pulses of 25μs width generated using NRT software and delivered via speech processor in case of Nucleus 24M cases, whereas Zebra software and the DIB will be used with Medel C40+ cases.
- All electrodes in recording EABR and 3 electrodes (apical, mid and basal) in recording EMLR will be tested in monopolar fashion. The stimulus current level will be set at C-level and then decreased by 10 current units steps till a response appears, then stimulus current level will be decreased by 5 current units steps till reaching the threshold.
- In case of uncooperative children, the initial stimulus current level will be set at 150 current units and then increased by 10 current units steps till a response appears, then the level will be decreased by 5 current units steps till reaching the threshold.
- The stimulus will be presented at a rate of 49 pulses/s in case of EABR and 9.3 pulses/s in case of EMLR.
- **Recording parameters:**
  Responses will be recorded on a separate computer by means of a trigger pulse sent by the PPS with Nucleus 24M cases and DIB with Medel C40+ cases to the evoked potential computer to synchronize the recording window with stimulus presentation.

- Electroencephalographic signal (EEG) will be recorded from surface electrodes placed on the forehead (positive), mastoid ipsilateral to the implant (ground) and contralateral mastoid (reference).

- EABR recording will include two replications of 1000 sweeps which will be amplified and band pass filtered between 150-3000 Hz. The analysis time will be 10 ms. The latency of every peak and interpeak intervals as well as the amplitude measured from peak to peak will be calculated.

- Subjects will be instructed to be awake in case of EMLR recording and two replications of 500 sweeps will be amplified and band pass filtered between 5-500 Hz. The analysis time will be 50 ms. The latency of every peak and amplitude measured from peak to peak will be calculated.
General testing instructions

- Room: Quiet room with minimal distraction
- Position of the patient sit just behind and to the patient 40 cm from the implanted ear
- Stimulus: with vowels computer pictures or written words associated with live voice and symbolic cards with consonants.
- Adjustment of live voice is done by using hand-held sound level meter starting at 60 dB SPL; if cannot detect voice sound is elevated 10 dB SPL
Assessment of Auditory perception of vowels

- Detection of speech sounds
- Vowel differentiation
- Vowel identification: A) Isolated vowels B) syllables
- Indicate 2 words same or different
- Identify vowels that differ in height
- Identify vowels that differ according to tongue advancement
- Identify vowels that differ in length
- Identify from a set of four words.
- Arabic vowels identification

Assessment of auditory consonant perception

- Done after vowel testing
- Consonants are classified according to manner of articulation into plosives, fricatives, nasal, glides and lateral sounds

**FIRST STEP**
Level one: Recognition of the sound.
Level two: discrimination from vowels.
Level three: discrimination according to voicing.
Level four: discriminate based on place of articulation.
Level five: discrimination from other groups.
Level six: identify sound from a set of four consonants.
- **SECOND STEP:**
  Discrimination between words that differ in a consonant (final, middle or last position)
Eight cases were studied

5 cases N24M
3 cases Medel

2 C40+
1 C40

2 post lingual
6 prelingual (one adult)
Age range: 6-25 y

NRT Results

- Two cases had responses from all electrodes
- One case had responses from all electrodes except E1 and E2
- One case had responses from all electrodes except E1, E2 and E3
- One case had responses from all electrodes except E1-E5
EABR Results

- **Nucleus 24M cases:**
  Two cases had responses from all electrodes.
  One case had responses form all electrodes except E1, E2 and E3
  One case had responses from all electrodes except E1-E5.
  One case had absent response from all electrodes.

- **Medel cases:**
  Two cases had responses from all electrodes except the last apical electrode
  One case had responses from only E1-E4
EMLR Results

- **Nucleus 24M cases:**
  Two cases had responses from the 3 examined electrodes
  Two cases had responses from the apical and mid but not from the basal electrode
  One case had no responses

MLR Results

- **Medel cases:**
  Only one case had responses from the 3 examined electrode.
Speech Perception Results

- All cases have shown 100% ability to detect vowels except one case.
- All cases showed difficulty to perceive vowels with close spectral analysis.
- All cases were able to differentiate consonants from vowels.
- Difficulty to differentiate /f/ and /θ/ and /l/ and /r/
CASE 1

- Male 6 y
- Onset of HL: 2 y of age
- Etiology: Ototoxicity
- Implanted (full insertion) with Medel C40+ and using Tempo+ speech processor (29/7/06)
ELECTROPHYSIOLOGY

- EABR was recorded from only the first four electrodes.
- EMLR was absent from the three electrodes
Auditory Consonant Perception

- Able to detect and recognize different consonants except /m/ and /n/ which were detected but not recognized.
- Able do discriminate from vowels.
- Difficulty to discriminate between sounds with different voicing.
- No difficulty to discriminate between groups except nasals from plosives, fricatives, laterals and glides.
- Difficulty to identify sound from a set of four consonants.
CASE 2

- Female, 22y
- Onset of HL: 3 ys of age
- Possible etiology: Usher syndrome
- Implanted (full insertion) with Nucleus 24M CI and fitted with Sprint speech processor (8/1/06)
EMLR

- She had EMLRs from electrodes 20 and 10 but no recorded responses from E3
Aided Thresholds
CONSONANT

- All sounds were detected and recognized
- All consonants were discriminated from vowels
- No difficulty in discriminating consonants according to voicing.
- No difficulty in discriminating consonants according to place of articulation except /f/ and /ø/
- No difficulty to discriminate between different consonant groups
- No difficulty to identify from a set of four consonant except sets containing /f/ and /ø/
To Conclude

The vision of this research:

- To use the systematized evaluation which will be used for outcome measures to monitor map programs during the training

THANK YOU