INTRA-OPERATIVE COCHLEAR IMPLANT MEASUREMENTS

SAMIR ASAL M.D

1- Cochlear Impedance Telemetry
Cochlear implants used presently permit bi-directional communication between the inner and outer parts of the device.

In practice this means that both stimulation and reading of the response of the physiological system to electrical stimuli transmitted via the implant are possible.

Measurement of the electrode impedance defines the electrical resistance in the place of contact between the electrode and the tissue (i.e., the measure of resistance to the flow of electrical current).

It reflects the electrical status of the electrode and its adjacent tissue environment.
Clinical significance

1- By measuring for example the monopolar impedance of each electrode, we can investigate electrode's overall functionality, and detect problems such as short-circuit or a break.

   In this way it is possible to determine which electrodes should be excluded from stimulation as well as how the stimulation level should be adjusted because of voltage compliance.

Clinical significance

2- Measurements of impedance made during the operation help inform the operator about the registered electrical resistance.

   When this information is analyzed together with the anatomic conditions, a decision about subsequent procedure can be made (e.g. the electrode should be inserted more deeply or the electrode should be moved slightly back).
Electrically Evoked Compound Potential (ECAP) Action

Telemetry capabilities became commercially available in 1998 to measure the electrically evoked compound action potential (ECAP) from the auditory nerve in cochlear implant (CI) recipients.

Now that ECAP measures are readily available in the clinical software for all three FDA-approved CI manufacturers and more clinicians are using these measures as part of routine clinical service delivery.
What is the ECAP?

The ECAP represents a synchronous response from electrically stimulated auditory nerve fibers and is essentially the electrical version of Wave I of the ABR.

The ECAP is recorded as a negative peak (N1) at about 0.2-0.4 ms following stimulus onset, followed by a much smaller positive peak or plateau (P2) occurring at about 0.6-0.8 ms.

The amplitude of the ECAP can be as large as 1-2 mV, which is roughly larger in magnitude than the electrically evoked ABR.

There is some differences between electrically and acoustically evoked CAP

1- CM and SP are not recorded in response to electrical stimulation

2- amplitude of N1 component of ECAP is larger and latency is shorter than acoustically evoked CAP

3- the rate of growth of ECAP with increasing stimulation level is steep when compared with its acoustic counterpart
Recording of ECAP

Because the ECAP is an early-latency evoked potential, there are challenges associated with separating it from stimulus artifact.

We have two methods for recording and separation of noise from response

1- The Forward-Masking Subtraction Method
2- The Alternating Polarity Method
The Forward-Masking Subtraction Method

four stimulus conditions are presented: (1) probe stimulus alone, (2) masker stimulus followed by the prob, (3) masker stimulus alone, (4) zero-current pulse to elicit system artifact

MPI is the time between offset of the masker and onset of the probe in the masker-plus-probe condition. Ideally, the MPI should be sufficiently short to ensure that most auditory nerve fibers are fully within their refractory period (e.g., 300-500 msec)

The Alternating Polarity Method

Responses are measured for negative-leading (cathodic) and positive-leading (anodic) biphasic pulses.

Reversing the polarity of the stimulus results in reversing the polarity of the artifact. However, the polarity of the neural response remains the same.

Upon averaging responses from both polarities, the majority of the stimulus artifact cancels out, leaving the neural response
Stimulation and Recording Parameters

1- Recording Delay
   it is the amount of time between offset of the probe pulse and onset of recording. It help to avoid saturation of the recording amplifier and is user-controlled only in NRT

2-Recording Electrode
   The default recording electrode is two electrode apical to the stimulating electrode

3-Current level

4-Amplifier gain

5-Stimulation rate

6-Number of averages

Finding Threshold

1- visual detection to determine the lowest stimulus that elicits a measurable response

   This method can use either an ascending or descending stimulus level.

   One drawback to the visual detection method is that for systems with a relatively high noise floor, the true threshold can be obscured by the noise, yielding a threshold estimate that is likely too high
2- linear regression analysis

Threshold is determined as the level at which the regression line crosses zero amplitude.

The advantage to this method is that lower thresholds can be extrapolated for high-noise systems.

One drawback to this method is that at least three suprathreshold data points are needed to reasonably calculate a regression.
Neural Response Telemetry (NRT)

NRT is the ECAP telemetry software used with the Cochlear Corporation implants.

NRT has been integrated with the Nucleus Custom Sound software (Custom Sound EP) so that ECAP threshold information can easily be used to aid in creating speech processor programs, or maps.

NRT uses the forward-masking subtraction paradigm as the default artifact reduction method.

The software has a built-in algorithm that marks the negative (N1) and positive (P2) peaks of the ECAP, calculates the peak-to-peak amplitude difference, and then plots that difference as a function of current level.
Neural Response Imaging (NRI)

NRI is the ECAP telemetry used in Advanced Bionics devices.

It was first introduced in 2001 and FDA approved in 2003 as an integrated part of the SoundWave software.

NRI uses alternating polarity for artifact reduction.

NRI has a built-in algorithm that marks the negative and positive peaks of the ECAP, calculates the peak-to-peak amplitude difference, and then plots that difference as a function of current level.

Auditory Nerve Response Telemetry (ART)

ART is the ECAP telemetry used in Med-El devices.

It was FDA approved in 2007 as an integrated part of the Maestro software.

ART uses alternating polarity for artifact reduction.

ART has an automated algorithm that marks the negative (N) and positive (P) peaks of the ECAP, calculates the peak-to-peak amplitude difference, and then plots that difference as a function of current level.
Clinical Uses for ECAP Measures

Over the past decade there has been a steady increase in the number of studies addressing the clinical utility of ECAP measures. In general, ECAP measures are clinically useful for a number of applications, including:

1- Objective verification of auditory nerve function in response to electrical stimulation
2- Objective verification of electrode/device function
3- Assistance in programming the speech processor for individuals who cannot provide reliable behavioral responses
4 -Verification or confirmation of the accuracy of questionable behavioral responses
The correlations between ECAP thresholds and behavioral levels are generally not strong enough to recommend using ECAP measures as a sole means to program the processor.

However, ECAP thresholds can be especially useful when coupled with other objective measures such as the electrically evoked stapedial reflex threshold or limited behavioral information.

Further, ECAP thresholds represent a level at which the stimulus should be audible enough to begin conditioning a child to respond behaviorally.