Intrascalar ECoG in Cochlear Implant Recipients

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Background:
Cochlear implants (CIs) are typically performed in patients with at least a moderate-to- profound sensorineural hearing loss. Recently, we demonstrated the availability of intracochlear round window (RW) electrocochleography (ECoG) during cochlear implantation and its potential clinical utility to assess the neural substrate required for electrostimulation. As such, we showed good correlations between certain components of the ECoG and postoperative CI performance. To further refine this technique, intracochlear recording options may provide an even better signal so that intracochlear electrode placement can be optimized via real-time intraoperative feedback. Since the recording probe (CI electrode) could be brought in close proximity to the source generators within the cochlea, this technique might also provide a means to record from various locations and thus discern cochlear regions based on their residual functional capacity.

Educational Objectives:
- Electrocochleography (ECoG) is a complex test that sometimes provides information on labyrinthean pathologies such as Meniere’s disease. A more detailed analysis of this signal, however, provides useful information during cochlear implantation.
- Understand the potential utility of electrocochleography during cochlear implantation both to assess the neural substrate for electrical stimulation as well as the clinical application of this recording algorithm for a real-time monitoring system during electrode insertion.
- ECoG is typically not well understood and its presence in cochlear implant candidates has not been known. At the conclusion of this presentation, the participants should have a better understanding of the complex nature of the ECoG and its potential utility to better assess the neural substrate for electrical stimulation via a cochlear implant. Also, participants will learn about real-time intracochlear monitoring as a future clinical tool during electrode insertion.

Aims:
Intracochlear recording sites might allow for improved signal to noise ratios and thus improved recording options for electrocochleography (ECoG) during human cochlear implantation.

Study Design:
Human Subject Inclusion Criteria
- UNC IRB Protocol number 05-2616.
- 17 pediatric and adult subjects undergoing cochlear implantation.

Surgery and Recording Set-up
- Foam insert attached to sound tube in EAC.
- Active recording input: monopolar probe (Neurosense, Magstim Co., Wales, UK).
- Return: surface electrode on the contralateral mastoid; common: surface electrode on the glabella.

Sound Stimulation and Evoked Potential Recording
- Sound delivery via Esyphone speakers.
- Recordings from the RW were in response to suprathreshold stimuli.
- Frequencies: 750, 1000, 2000, 4000 Hz.
- Tone bursts: 1-4 ms rise & fall times, Blackman window.
- Duration: 28 ms (250-750 Hz) or 10 ms (1000-4000 Hz).
- Frequency series tested at 90 dB nHL. Then, a frequency with a good response (typically 500 Hz) was used for a level series decreasing from 90 dB nHL in 5-10 dB steps.
- Recordings with the sound tube crimped were taken at 90 dB nHL at each frequency to estimate electrical artifact, if any.
- Recordings were started 4 ms prior to stimulus onset and the recording epoch ended 2 ms after.
- Recordings from the RW were in response to suprathreshold stimuli.
- Recordings were taken at 90 dB nHL at each frequency to estimate electrical artifact, if any.
- Routinely took less than 10 minutes to administer the intraoperative recording protocol used in the study.

Data Analysis
- Condensation and rarefaction stored separately.
- Spectrum obtained via Fourier transform (FFT).
- Significant response: magnitude of the peak larger than noise level by three standard deviations.
- The noise and its variance were determined from six bins, three on each side of the signal starting two bins away from the peak.

Results:
- Round window as well as intracochlear ECoG allows recording of robust early auditory potentials.
- Real-time signal processing algorithms can identify the various components of the ECoG signal, namely the cochlear microphonic (CM) from hair cells, the compound action potential (CAP) from the spiral ganglion, the auditory nerve neurophonic (ANN, phase locked neural potential) and the summing potential (SP).
- Recordings at the round window membrane demonstrated robust potentials in most patients. With an intracochlear electrode positioning, however, signals showed markedly better amplitudes than at the RW in 16/17 patients.

Discussion & Conclusions:
- Intraoperative set-up feasible
- Recording times feasible for clinical use (using suprathreshold stimuli)
- Intracochlear recording sites are promising demonstrating strong responses
- Recordings through implant’s telemetry system might not be accurate enough; modified electrode carriers seem to represent a better option.
- Data on longitudinal insertions complex; correlation with imaging in the future
- Further intraocular experiments will likely identify patterns that will help to improve intracochlear electrode placement.

Table 1: Subjects recorded.

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<th>TotalPower(µV²)*</th>
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Figure 1: Concept of an intraoperative recording system providing feedback during cochlear implantation using an acoustic sound generator placed within the external auditory canals. The implant could be used to provide recordings during the insertion process. The recordings need to be timed with the acoustic stimulation via a trigger mechanism.

Figure 2: Typical electrophysiological responses obtained at the round window. The image demonstrates a frequency series of a 10 ms stimulus with 2 ms rise and fall times. The image depicts the cochlear microphonic (CM) with the embedded compound action potential (CAP). The CM is present for the stimulus duration, whereas the CAP is the synchronized response at the stimulus onset.

Figure 3: Comparison of round window and intrascalar ECoG. Upper panel shows the raw waveforms obtained at both locations, whereas the black line denotes recording obtained at the round window membrane and the blue line shows the intrascalar response. Note the difference in signal magnitude with a marked increase from within scala tympani. The bottom panel shows the frequency spectrum of the same responses.

Figure 4: Microscopic view of the recording electrode placed within the facial recess onto the round window. As a measure of current electrode position and orientation.

Figure 5: Clinical set-up. A: Draping and prepping process. The photo shows the auricle folded anterior. The sound tube is visible under the drapes so it can be clamped during the case to exclude artifacts. B: Microscopic view of the recording electrode placed within the facial recess onto the round window.

Figure 6: Distribution of response changes from the initial round window recording site to the intrascalar location. The upper panel denotes response changes at the best frequency for each subject and the lower panel demonstrates response changes across all frequencies and intensities tested.

The x-axis shows the response change in dB. 0 denotes no change; a shift to the right indicates increased responses, which were observed in the majority of cases. A shift to the left, however, denotes a decreased signal intensity for the intracochlear recordings when compared to the ones obtained at the round window membrane.

Figure 7: In four cases several frequencies were tested. In each case the change in the intracochlear response compared to the initial round window recording site to the intrascalar location. Subject 17 was one of two cases where the intrascalar response was reduced compared to that at the round window. This case had an enlarged vestibule/aqueduct and perilymph pushed out after the round window was opened.

Figure 8: In four cases several frequencies were tested. In each case the change in the intracochlear response compared to the initial round window recording site to the intrascalar location. Subject 17 was one of two cases where the intrascalar response was reduced compared to that at the round window. This case had an enlarged vestibule/aqueduct and perilymph pushed out after the round window was opened.