Ninth Quarterly Progress Report

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Effects of Remaining Hair Cells on Cochlear Implant Function

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1 Introduction

In this contract, we are conducting physiological and computational model experiments to assess the effects that functional hair cells have on the auditory nerve's response to electrical stimulation. This work is relevant to a widening pool of cochlear implant candidates as audiological criteria (e.g., pure-tone thresholds) are becoming more relaxed and patients with residual hearing are being implanted. Intact hair cells may interact with or modify electrical stimuli in several ways. Acoustically evoked neural activity may interact or compete with electrically evoked activity. It is also possible that the very presence of viable hair cells - without any exogenous acoustic stimuli - can modify electrically evoked neural responses. For example, electrical stimuli may depolarize hair cell membranes and initiate the release of neurotransmitter, resulting in nerve-fiber activation. It is also possible that the spontaneous release of neurotransmitter may modulate the response characteristics of nerve fibers, thereby changing their responsiveness to electrical stimuli. The experiments of this contract are designed to acquire evoked potential data from sets of experimental animals that have functional and nonfunctional hair cells. Comparisons will then be performed to assess the effect of functional hair cells on the transduction of electrical stimuli delivered by intracochlear electrodes.

2 Summary of activities in this quarter

In our ninth quarter (1 July through 30 September, 2001), the following activities related to this contract were completed:

1. We hosted a productive meeting with our consultant group consisting of Don Eddington, Blake Wilson, and Bob Shannon to review progress on the contract as well as to discuss future directions of the research.

2. We attended the 2001 Conference on Implantable Auditory Prostheses at Asilomar Conference Grounds in Pacific Grove, California. Paul Abbas presented a summary of our work to date on this contract, describing both effects of hair cells on the responses to electrical stimulation as well as noise masking effects. Chris Runge-Samuelson presented a poster at that meeting describing effects of hair cells on response to continuous sinusoidal electrical stimulation.

3. We continued experimental recordings of binaural ABR component in animals with acoustic stimulation in one ear and electric stimulation

of the opposite ear. That work is summarized in this QPR

3 The binaural ABR response to combined acoustic and electric stimulation

If cochlear implant users have significant hearing in the implanted ear, they will likely be in a position to take advantage of acoustic stimulation, possibly with amplification, in the ear opposite the implanted ear. Therefore, it is of interest to investigate the degree to which the binaural auditory system may be able to process combinations of acoustic and electric stimulation from the two ears. If significant central interactions occur, then it may be desirable to manipulate the presentation of the electric and acoustic stimuli so as to control this interaction.

To examine this issue with our animal models, we have chosen to adapt the measurement of the binaural ABR component (Dobie and Berlin, 1979) for use with electric and acoustic stimuli presented to opposite ears. This component uses auditory brainstem response measures to assess the degree of central neural interaction of the input from the two ears. As it is based upon the ABR response, this measure is somewhat limited in that we cannot isolate the particular location of interaction or specific temporal aspects of signal encoding. However, we view this measure as a useful initial assessment of binaural neural interaction. As the ABR is highly dependent upon a synchronized neural response, the binaural ABR component may be particularly sensitive to the differences in stimulus levels and timing of stimulus presentation. Such variables are clearly of interest for efforts to control the degree of binaural interaction. Our proposed investigation of the binaural ABR involved two steps. First, we proposed an initial assessment of the electric-acoustic interaction component using wide-band, pulsatile stimuli that would excite wide regions of the cochlea. Depending on the results obtained with those stimuli, subsequent assessments would employ more frequency- and place-specific stimuli so as to obtain a more detailed analysis of acoustic-electric interactions.

The efficient assessment of binaural interaction requires an animal model that would presumably maximize the acoustic-electric ABR interaction component. To that end, we used animal preparations in which one ear was deafened and implanted with an intracochlear electrode while acoustic sensitivity of the contralateral ear was left intact. This hearing-deafened model also provided sufficient flexibility to examine various degrees of interaction.

To accomplish this, we used anesthetized guinea pigs in acute preparations. Preliminary click-evoked ABR measures were obtained to confirm normal hearing sensitivity. The bulla of the left ear surgically accessed and the round window membrane was partially excised. The cochlea was deafened with 50 microliters of 10 percent (w/v) neomycin sulfate, administered over several minutes through 8-10 repeated aspirations of perilymph and infusions of the solution. This was done to assure adequate diffusion through the cochlea. Electrical stimulation was delivered using a monopolar electrode inserted into the basal turn of the scala tympani. An earphone (Beyer DT-48) and speculum was positioned onto the external canal of the intact right ear. The electric stimuli consisted of 40 microsecond/phase biphasic pulses delivered through our isolated current source. Acoustic stimuli were broad-band clicks produced by driving the earphone with 100 microsecond/phase biphasic pulses and shaped by the characteristics of the earphone and speculum.

Auditory brainstem responses were recorded using positive and negative recording electrodes positioned along the midline at the vertex and the nape of the neck. Amplifier gain was 1000x. Responses were recorded for three stimulus conditions: right-ear stimulation alone, left-ear stimulation alone, and stimulation of both ears with their respective stimuli. The binaural ABR component was then computed by subtracting the sum of response waveforms for each ear alone from the waveform in response to binaural stimulation. That response, reflecting the nonlinearity in the system, is attributed to the binaural interaction occurring at the level of the brainstem. Data from a total of six guinea pig preparations were collected.

In these initial experiments, our goal was to assess the presence of the binaural component produced by this novel (acoustic and electric) stimulation paradigm. We therefore chose levels of the acoustic and electric stimuli so that the ABR response to stimulation of each ear would be similar in amplitude and clearly discernable above the noise floor. Furthermore, we reasoned that, as the latency of the brainstem response to acoustic and electric stimuli will be different (approximately 1-1.5 ms), the degree of binaural interaction will depend on the interaural time difference. Consequently, we chose appropriate levels of acoustic click and electric pulses and measured the binaural component as a function of interaural time delay. The amplitude of the binaural component is plotted in Figure 1 as a function of time delay between electric and acoustic stimulation. The peak in binaural response tends to be between 1 and 1.5 ms, which is approximately the latency

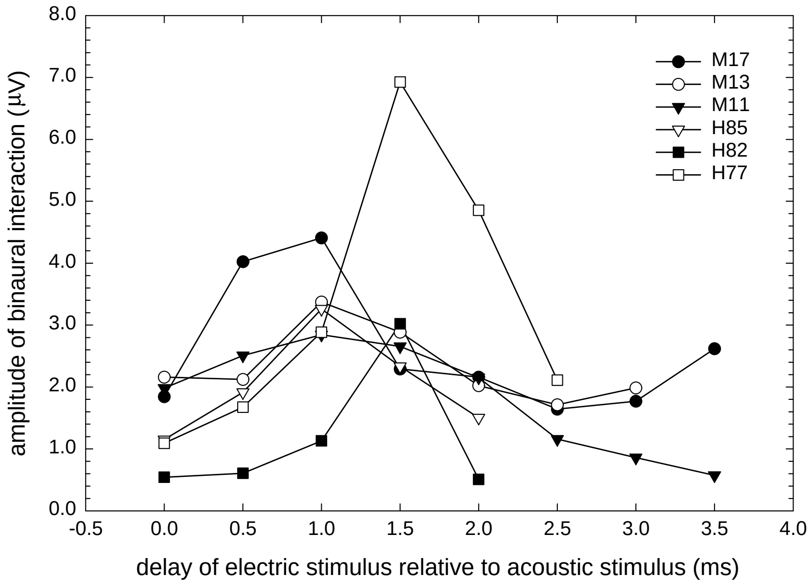

Figure 1: Effect of presentation of acoustic stimulus in one ear and electric stimulus in the contralateral ear. Plotted is the amplitude of the binaural ABR component as a function of delay between acoustic click (presented to right ear) and electric biphasic pulse (presented to the left ear). Data from 6 guinea pigs are shown. The binaural interaction component produces a peak when the electric stimulus is delayed (relative to the acoustic stimulus) by 1 to 1.5 ms.

difference between acoustic and electric responses at the level of the auditory nerve. While the amplitudes of these measures varied across subject and were generally small, they demonstrate similar trends.

These experiments have demonstrated the presence of a binaural ABR component in response to combined acoustic and electric stimulation as well as demonstrating a strong dependence of that interaction on interaural delay. However, as is evident in Figure 1, the magnitude of the electric-acoustic binaural interaction component is relatively small. We therefore believe that it would be difficult to use this approach for more detailed assessments employing frequency- or place-specific stimuli. However, we are in the process of assessing the use of depth electrodes in the inferior colliculus to better isolate the source of the potentials and improve the signal-to-noise ratio in the recording environment.

4 Plans for the next quarter

In the tenth quarter, we plan to do the following:

- We will conduct additional experiments to assess the degree effects of adaptation with acoustic noise.
- We will conduct further experiments with inferior colliculus recordings of binaural interaction of acoustic and electric stimulation.
- We will begin ototoxic antibiotic treatments of cats to effect partial hearing losses in these animals. These subjects will then be used as a more realistic model of the pathology encountered in candidate implant patients.

References

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