Predicting objective measures of the electrode-neuron interface with an auditory model

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Abstract

The ability of a cochlear implant (CI) to restore hearing for a profoundly deaf person depends on the functionality of the electrode-neuron interface inside the cochlea. Functionality of that interface can be assessed by measuring characteristics of electrically evoked compound action potential (eCAP) responses with the help of the two-way telemetry functionality of the implant. Interestingly, studies with non-human mammals have shown the magnitude of the effect caused by prolonging of the inter-phase gap (IPG) in the charge-balanced (symmetric) biphasic pulse on the slope of the eCAP amplitude growth function (AGF) to be indicative of cochlear health. Problems in translating such promising results into benefits for CI users have raised questions about other, non-neural influences that could be behind the correlations found in animal studies. Here, we decided to approach the question from a computational modeling point of view. To that end, we designed a simplified 2-D model to emulate in a phenomenological way how the electrical signal from the stimulating electrode contact reaches the auditory nerve fibers (ANFs) distributed along the cochlea, evoking the ANFs to create action potentials that can be recorded as a compound response at one of the recording electrodes. The geometrical constrains of the model were derived from post-operative and posthumous neurophysiological data from literature. A phenomenological model for the electrically stimulated ANF was used to predict the spiking responses of the individual ANFs and the spiking outputs were convolved with a unitary response function to derive the eCAP signal. We applied such a model in simulated eCAP AGF measurements varying both the IPG of the stimulus as well as the neural survival along the cochlea. We obtained predictions that are in line with the data from literature: Prolonging of the IPG was found to result in steeper eCAP AGF slopes and smaller eCAP threshold values, the size of the effect on the slope increasing with increased neural survival. In summary, our study shows how auditory models can be used to test data- or hypothesis-driven theories of effects on objective measures of CI user's electrode-neuron interface.

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