Proceedings of The First Joint BMES/EMBS Conference **Serving Humanity, Advancing Technology** Oct. 13-16, '99, Atlanta, GA, USA

Methods for modeling the relationship between extracellular recording variability and impedance properties of chronic neural implants

Justin C. Williams (jcwill@asu.edu), Daryl R. Kipke
Bioengineering Program, Arizona State University, Tempe, AZ 85287

Abstract – A finite element model has been developed to investigate the theoretical relationship between changes in extracellular resistivity and electrical potential in a chronic extracellular recording scenario. The inputs to the model are experimental results obtained from chronic recording and complex impedance measurements in cerebral cortex of adult guinea pigs. Using the measured tissue-electrode impedance to set the resistivity in the model provides simulated extracellular potentials that are consistent with the measured spike amplitudes. In both the experimental and theoretical paradigms it was found that increased extracellular resistivity results in an increased potential at the recording electrode tip. Although the results of the two methods could not be directly correlated, they do suggest that a certain amount of variance can be accounted for by the increased resistivity values. The methods presented offer a powerful theoretical tool for understanding some of the factors, which may affect chronic extracellular recording stability.

I. Introduction

The recorded neural signals in chronic multichannel electrodes can be highly variable from day to day. While strict signal stability is not required in many neuroscience experiments, the issue begs understanding. It is hypothesized that the main components of this variability come from several sources, including relative motion between the brain and skull. A certain amount of variability may arise due to a change in the extracellular medium caused by a reorganization of extracellular constituents during tissue insult and the subsequent reaction and healing processes. It is the objective of this study to use an engineering approach to look at the effects that encapsulation may have on the complex electrical properties of the neural recording system using state-of-the-art electronic measurement and modeling techniques. These methods are then used to evaluate how encapsulation may account for a portion of the variability exhibited in extracellular recording.

II. Methods

Experiments were performed on adult guinea pigs. Animals were implanted with 4x3 arrays of tetrodes (custom made in-house). Each tetrode consisted of four twisted 25 micron polyimide-coated platinum/irridium microwires. Before, during, and immediately after implantation, the complex impedance spectrum was measured for each electrode using a Hewlett Packard Precision LCR Meter (Hewlett-Packard Japan, LTD, Model# HP 4284A). Spectra were obtained daily during the first ten days post implant. Concurrent extracellular recordings were obtained on the same days in order to correlate recording stability with impedance spectra changes.

A finite element model (FEM) of the extracellular field surrounding the electrodes was developed utilizing a partial differential equation solution to the closed boundary field problem in two-dimensions. The FEM was then employed to simulate the effects of extracellular resistivity on extracellular field potentials seen at the electrode tip from neurons in close proximity. Results from the impedance monitoring experiments were used as inputs to the model to provide a correlation between the model's output and experimental observations.

III. Results

Initial results suggest that the real-resistive component of complex impedance exhibits the most significant change during the initial implant period. The resistive spectrum generally increased during this period, associated with a subsequent non-linear increase in spike amplitude in most cases. The results of incorporating the increasing experimental resistive values into the FEM gave theoretical extracellular field potential solutions which also non-linearly increased. The subsequent increases in potential from the model simulations were not, however, directly correlated with the observed increases in recorded potential from the chronic implant recordings.

IV. Discussion

In our chronic neural recordings, the variability in spike amplitudes from day to day are not directly predicted by the corresponding impedance variations of the electrode-tissue interface. Our current modeling analysis supports this complex relationship. There are many factors which can lead to non-linearities in the tissue-electrode interface. Any discontinuities in the properties of the extracellular medium, such as large groups of cells and even the electrodes themselves, can cause compression of the electric fields.

V. Conclusions

Although the results of the investigated model did not directly correlate with the observed experimental variance in extracellular recordings, a further understanding of the factors which affect the variability of the model may lead to a better understanding of the factors which affect variability in chronic extracellular recordings. Finite element models are a powerful analytical tool with which to study this problem. The extracellular field model can easily investigate many of the factors which are thought to affect extracellular recording stability. These include the effects that micro-motion, electrode geometry, encapsulation, and even the presence of large reactive cells around the electrode can have on the electrical potential seen at the electrode tip.

Acknowledgements

This work was funded in part by the NIH and the NSF.