Impact of Impedance Changes on Stimulation Estimates in a Pre-Clinical Model for Deep Brain Stimulation

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Introduction

Most clinical deep brain stimulation (DBS) systems deliver stimulation using a voltage-controlled pulse generator. For these systems, the amount of current delivered at the electrode can be affected by the impedance of the electrode. If the impedance of the electrode varies, then the current delivered through the electrode can also vary, and thus the voltage distribution generated in the target neural tissue can vary (Ranck, 1975).

In this report we demonstrate that in a preclinical model of DBS, impedances do change over time, and these changes are influenced by a number of variables. We also visualized the changes in Stimulation Estimates (SE) due to impedance changes with voltage and current controlled systems.

Methods

Thirty (30) pigs were implanted with bilateral DBS leads for either 30 days or 180 days. Impedance measurements were taken repeatedly throughout the study. SEs were created using Finite Element (Comsol 4.2a, Natick MA) and axon cable (NEURON 7.2) models, following the methods of McIntyre et al.

Image courtesy of Boston Scientific.

Figure 1 (left): Bilateral DBS leads implanted in the swine frontal lobe

Table 2 (bottom): Stimulation parameters used in the study. Each stimulation setting represented in the table was active in n=5 pigs for 30 days, and another n=5 pigs for 180 days.

Group	Frequency	Pulse Width	Amplitude
High Amplitude	139 Hz	90 µsec	10 mA
Long Pulse Width	139 Hz	1000 µsec	0.9 mA
High Rate / Frequency	1190 Hz	90 µsec	4.3 mA

Results

Impedances varied over time, even though stimulation parameters remained unchanged. SEs show changes in activated volumes due to impedance changes.

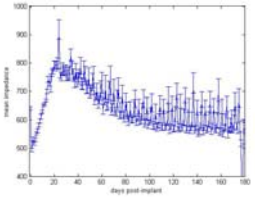

Figure 2. Mean impedance averaged across all contacts on each day post-implant.

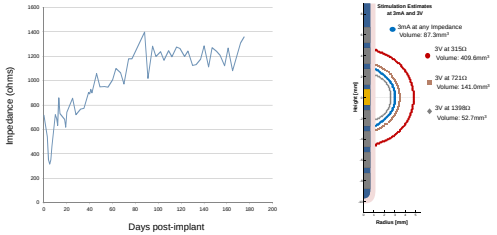

Figure 3. Left: Impedance on each day for the active contact of a single, High Amplitude animal. Right: Expected activated volumes from the computational model for a voltage-controlled system and a current-controlled system stimulating on this contact. The voltage-controlled system shows variability in activated volume due to the variability in impedance on this contact over time.

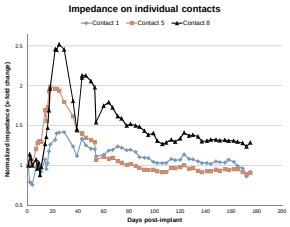

Figure 4. Impedance on each day for three contacts on the active lead of a single, Long PW animal. Impedance values are normalized as an x-fold change from the impedance on the first day post-implant.

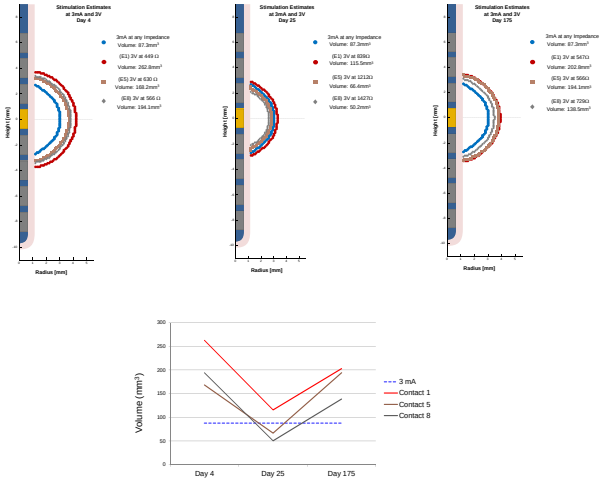

Figure 5. Top row: Expected activated volumes from the computational model for a voltage-controlled system and a current-controlled system, stimulating on contacts with the impedances shown in Figure 4, at day 4, day 25, and day 175 post implant. Bottom: The voltage-controlled system shows variability in activated volumes over time, due to the variability in impedances. Activated volumes can be larger or smaller than the activated volume expected with a current-controlled system.

Discussion

Previous researchers (Lempka et al, 2010) have proposed that instability in impedances could be partially responsible for the frequent need to reprogram stimulators in DBS patients. The SEs observed in this study are consistent with this hypothesis.

Conclusions

The impedance instability observed in this animal model would be expected to result in changes in the activated volume for voltage-controlled DBS systems, while current-controlled pulse generators may deliver stimulation that is less affected by changes in impedance.

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