Impedance Changes Over Time in a Pre-Clinical Model for Deep Brain Stimulation

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Background

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 will be affected by the impedance of the electrode. If the impedance of the electrode varies over time, then the amount of current delivered through the electrode will also vary, and thus the voltage distribution generated in the target neural tissue will vary. Previous researchers (Lempka et al, 2010) have proposed that such instability in impedances could be partially responsible for the frequent need to reprogram stimulators in DBS patients.

In this report we demonstrate that impedances do change over time in a preclinical model of DBS and that these changes are influenced by a number of variables, such as the position of the electrode on the lead, and whether the lead delivered electrical stimulation. As a result, electrodes on the same lead can undergo different impedance changes.

Methods

Thirty (30) pigs were implanted with bilateral DBS leads for either 30 days or 180 days. Each animal was randomly assigned one lead that delivered stimulation, while the contralateral lead remained passive (no stimulation). Impedance measurements were taken 2-5 times weekly for the duration of the study.

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 fell over the first day post-implant, then rose significantly over the next 23 days post-implant (mean impedance on Day 1 = 492 Ω, Day 24 = 917 Ω; $p << .001$, paired t-test), then steadily declined until they stabilized at approximately Day 100 post-implant. In addition, more distal electrodes were lower impedance than more proximal electrodes. Finally, leads that delivered electrical stimulation showed higher mean impedances on all electrodes than leads that delivered no stimulation.

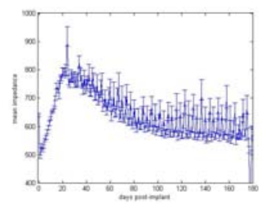

Figure 2. Mean impedance averaged across all contacts on each day post-implant.

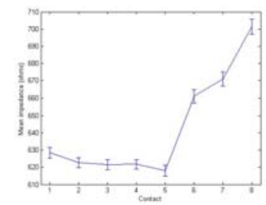

Figure 3. Mean impedance on each contact at all time points measured in the study. The cathode was always on contact 5, which was the lowest impedance contact. The highest impedance contact was the most proximal contact (contact 8).

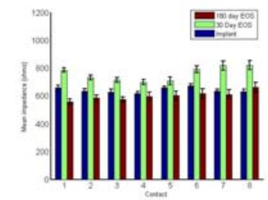

Figure 4. Mean impedance on each contact at implant, at sacrifice after 30 days, and at sacrifice after 180 days.

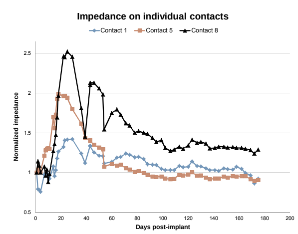

Figure 5. Impedance on each day for three contacts on the active lead of a single, Long PW animal. Impedance values are normalized to the impedance on the first day post-implant.

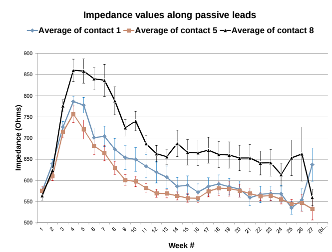

Figure 6. Mean impedance on each week for three contacts for all passive leads.

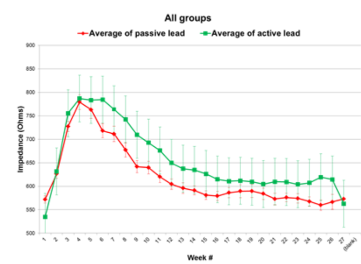

Figure 7. Mean impedance on all contacts each week, for active and passive leads. Active leads had higher mean impedances.

Conclusions

Based on previous theoretical and experimental work (Butson et al, 2006, 2008; Miocinovic et al 2009), these variations in impedance would be expected to result in changes in the current at each electrode for voltage-controlled DBS systems, while current-controlled pulse generators may deliver stimulation that is less affected by changes in impedance. For further analysis of stimulation-related impedance changes in this model, see related posters from Jackson et al. and Steinke et al.

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