ACUTE IMPEDANCE CHANGES DURING PROGRAMMING & CORRESPONDING STIMULATION ESTIMATES

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Background

The impedances of implanted electrodes have been observed to vary both after implantation and with stimulation [Benabid 1996, Lempka 2009, Miocinovic 2009, Lempka 2010]. We sought to investigate short-term impedance changes induced by mock MonoPolar Review (MPR) in a live model and visualize changes in Stimulation Estimates (SEs) based on those impedance changes.

Historically, Deep Brain Stimulation (DBS) has been delivered using voltage-controlled pulse generators with a single voltage source. The therapeutic fields generated by these systems are subject to the varying impedance measured at each lead electrode. More recently, stimulators with single or multiple current sources have been proposed. Multiple, independent current sources may allow for constant stimulation even with changes in impedances on each electrode, or between electrodes.

Methods

Five juvenile pigs were implanted with bilateral active DBS leads in each frontal lobe of each animal. A BSC2201 DBS lead with standard electrode sizes (~6mm^2) was placed in one hemisphere, and a prototype lead including electrodes of a smaller size and non-cylindrical geometry was implanted in the contralateral side. A four part protocol was performed (>20 days post-implant), during which the animals were exposed to a series of stimulation settings, increasing current on each individual electrode. Stimulation was OFF for >12 hours prior to start of study. Only partial data was available for pig 5.

For each animal, a 4-block protocol was attempted. In each block, impedance for all electrodes on both leads was recorded by the DBS system, once every 45-60 seconds. The protocol is shown below in Table 1. Block 1: stim OFF. Block 2: MPR on standard lead. Block 3: MPR on prototype lead. Block 4: ON on both leads. The protocol for the MPR is shown below in Fig. 1. The settings for the ON block were: 3mA, 60µs, 130Hz, electrode #3. Protocol blocks were performed in order, but not in all cases immediately following one another.

Data are plotted in percent change, by normalizing to the first impedance value in each block, for each electrode on each lead.

Stimulation Estimates were created using finite element (Comsol 4.2a) and axon cable (NEURON 7.2) models, following the methods of McIntyre et al.

Results

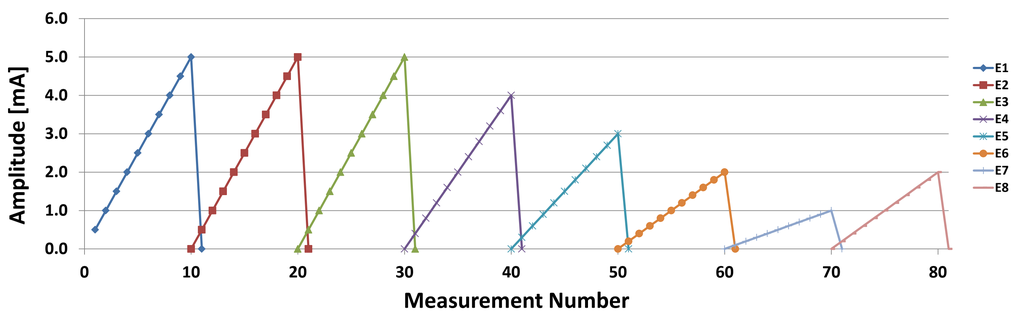


Figure 1. Putative (contrived) Monopolar Review (MPR). Distal electrodes of the lead were said to be 'within target', thus higher amplitudes were explored. Moving from distal to proximal electrodes, the maximum amplitude was lowered. Each electrode was active for the same number of data points (10) - approximately 8 minutes. A single electrode was active at any time. Stimulation delivered with 60µs pulsewidth at 130Hz.

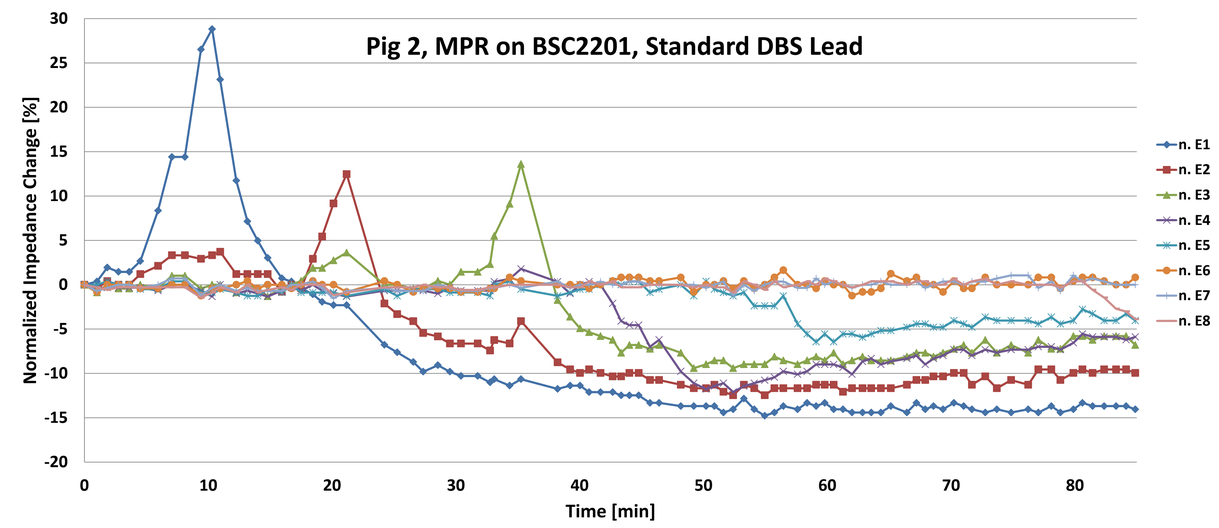
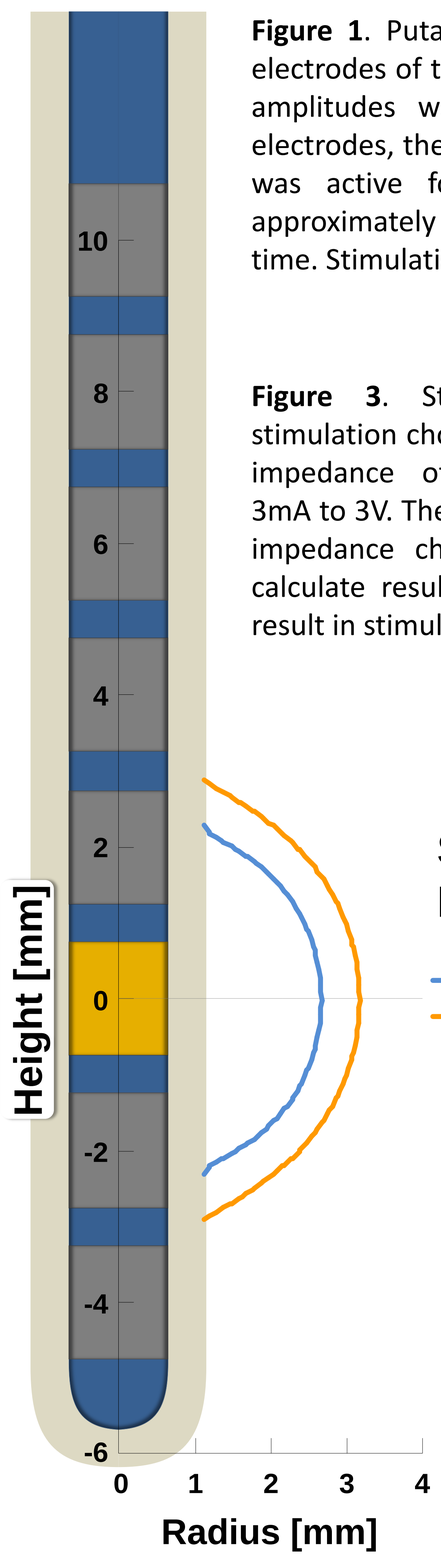


Figure 2. Selected Normalized impedance change during MPR. Standard lead data, Block 2 of Pig 2. Impedance on active contacts both increased and decreased when the contact was active. Impedance on contacts neighboring an active contact also appear to deviate from baseline.



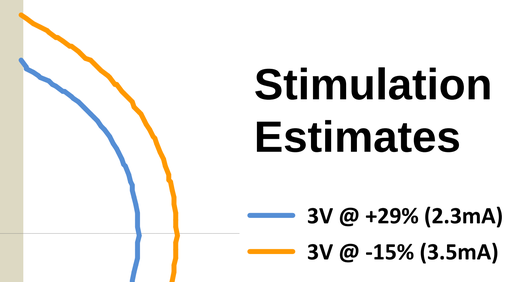


Figure 3. Stimulation Estimates (SEs). Nominal stimulation chosen as 3mA, 60µs (not shown); nominal impedance of 1000Ω assumed to convert from 3mA to 3V. The **maximum** (+29%) and **minimum** (-15%) impedance change shown in Fig. 2 were used to calculate resulting SEs for constant 3V programmed, result in stimulation at **2.3**mA and **3.5**mA.

Table 1. Stimulation Protocol

Protocol Block	Block 1	Block 2	Block 3	Block 4
BSC 2201	OFF	MPR	OFF	ON
Prototype Lead	OFF	OFF	MPR	ON

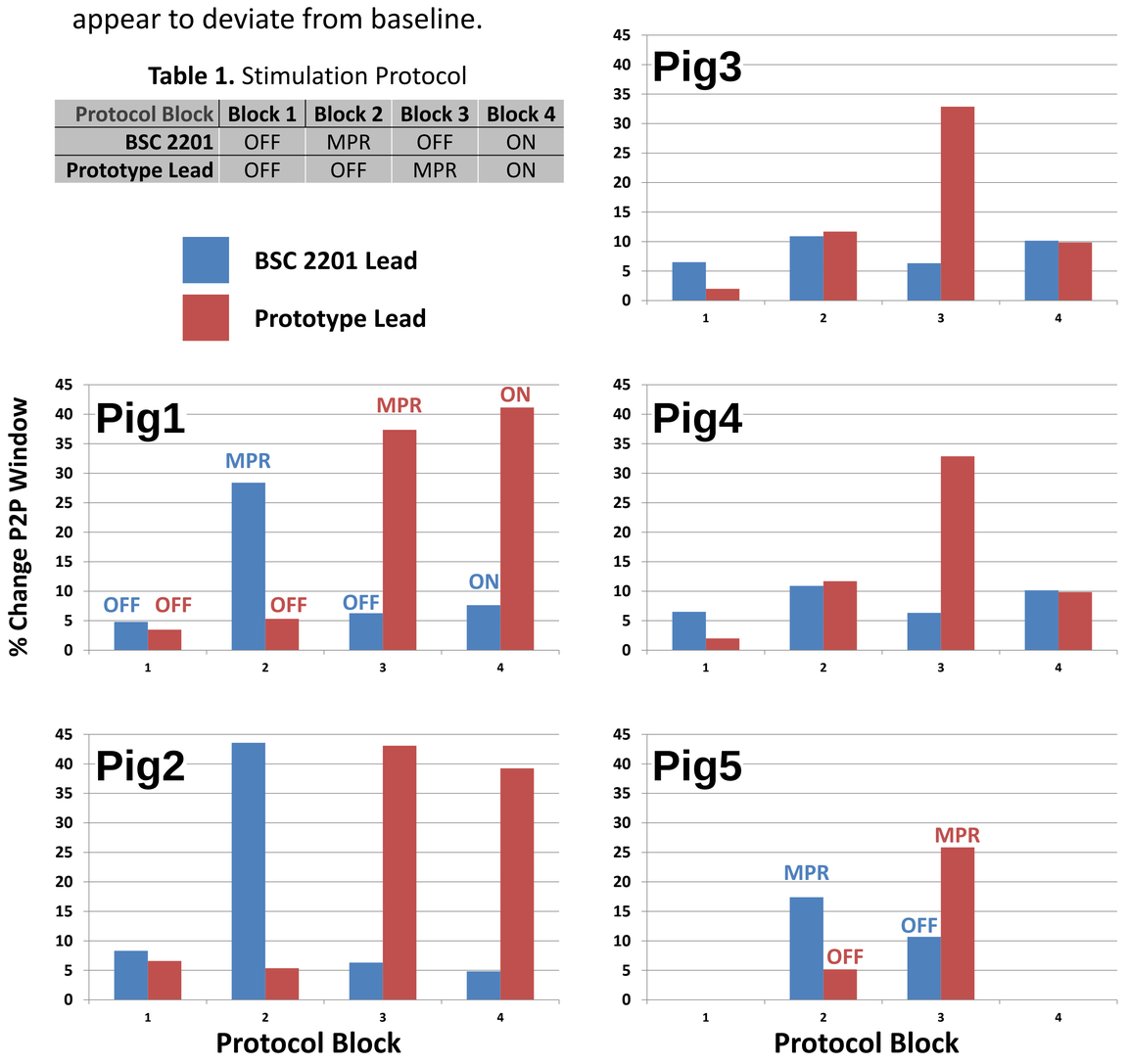


Figure 4. Maximum peak-to-peak impedance changes. For each electrode, the window between maximum and minimum impedance change was calculated for each protocol block. The maximum window was selected for each lead in each animal, shown above. Not all data available for pig 5.

Conclusions

Lempka et al., 2010 proposed that instability in impedances could be partially responsible for the frequent need to reprogram DBS patients. The animal model suggests that these impedance changes could occur on an acute timescale. Changes in impedances may result in changes in current at the electrode for a voltage-controlled system, such that any thresholds for efficacy or side effects measured during MPR could be different than those measured at some other time. Further studies should explore whether the same short-term impedance changes are observed during MPR in a clinical setting.

Presented at MDS 2013

The prototype lead is a concept device in development phase used in the preclinical research. Information concerning this device is only displayed for informational, educational research and scientific purposes.

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