Predicting Treatment Outcome in Spinal Cord Stimulation with EEG

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Introduction: Back pain is one of the most common causes of pain in the United States. Spinal cord stimulation (SCS) is an intervention for patients with chronic back pain (CBP). However, SCS decreases pain in only 58% of patients and relies on self-reported pain scores as outcome measures. An SCS trial is temporarily implanted for seven days and helps to determine if a permanent SCS is needed. Patients that have a >50% reduction in pain from the trial stimulator makes them eligible for permanent implantation. However, self-reported measures reveal little on how mechanisms in the brain are altered. Other measurements of pain intensity, onset, medication, disabilities, depression, and anxiety have been used with machine learning to predict outcomes with accuracies <70%. We aim to predict long-term SCS responders at 6-months using baseline resting EEG and machine learning.

Materials and Methods: We obtained 10-minutes of resting electroencephalography (EEG) and pain questionnaires from nine participants with CBP at two time points: 1) pre-trial baseline. 2) Six months after SCS permanent implant surgery. Subjects were designated as high or moderate responders based on the amount of pain relief provided by the long-term (post six months) SCS, and pain scored on a scale of 0-10 with 0 being no pain and 10 intolerable. We used the resting EEG from baseline to predict long-term treatment outcome. Resting EEG data was fed through a pipeline for classification and to map dipole sources. EEG signals were preprocessed using the EEGLAB toolbox. Independent component analysis and dipole fitting were used to linearly unmix the signal and to map dipole sources from the brain. Spectral analysis was performed to obtain the frequency distribution of the signal. Each power band, delta (1-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz), and gamma (30-100 Hz), as well as the entire spectrum (1-100 Hz), were used for classification. Furthermore, dipole sources were ranked based on classification feature weights to determine the significance of specific regions in the brain. We used support vector machines to predict pain outcomes.

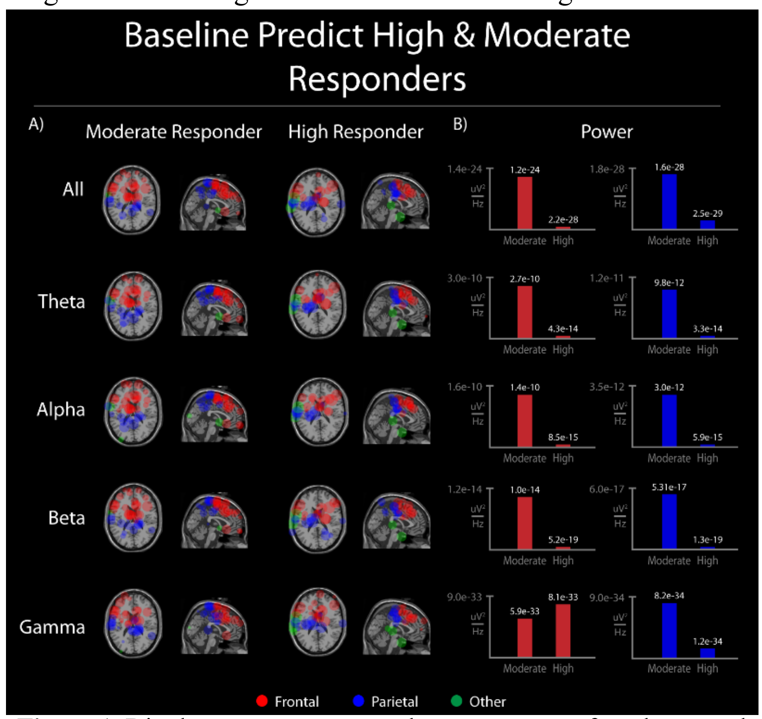

Figure 1. Dipole sources are mapped across groups of moderate and high responders showing changes in frontal and parietal regions in both location and power. The dipoles are represented as red (frontal), blue (parietal), and green (other) circles that increase in size as the dipole increases in importance.

Results and Discussion: We found higher frequency powerbands provide overall classification performance of 88.89%. Differences in power are seen between moderate and high responders in both the frontal and parietal regions for theta, alpha, beta, and the entire spectrum (Fig.1). This can potentially be used to predict patient response to SCS.

Conclusions: We found evidence of decreased power in theta, alpha, beta, and entire spectrum in the anterior regions of the parietal cortex and posterior regions of the frontal cortex between moderate and high responders, which can be used for predicting treatment outcomes in long-term pain relief from SCS. Long-term treatment outcome prediction using baseline EEG data has the potential to contribute to decision making in terms of permanent surgery, forgo trial periods, and improve clinical efficiency by beginning to understand the mechanism of action of SCS in the human brain.

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