

Neural Prosthesis Seminar

“Cellular Effects of Spinal Cord Stimulation: Model Experiment, and Design”

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Wolstein Auditorium, Wolstein Research
Building, Case Western Reserve University



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Abstract

Spinal cord stimulation (SCS) is an established treatment for chronic pain, but neither the neural substrate for SCS nor the relationship between the applied frequency of SCS and its clinical efficacy has been fully characterized. We developed and validated a biophysical model of the dorsal horn circuit and simulated the effects of SCS applied at between 5 Hz and 150 Hz on the activity of model wide dynamic range projection neurons. SCS at 30-100 Hz produced maximal inhibition of projection neuron activity. Furthermore, we quantified responses to SCS with diminished levels of inhibition in the dorsal horn to simulate the effect of disease progression. The degree to which projection neurons were inhibited by SCS declined as the strength of inhibitory mechanisms was reduced, and the optimal SCS frequency decreased. Our simulation results suggest that the efficacy of SCS is dependent on stimulation frequency and that the loss of dorsal horn inhibition during chronic pain may explain the decline in SCS efficacy over time. To evaluate these model predictions, we recorded the responses of antidromically identified projection neurons in the lumbar dorsal horn to different frequencies of SCS in acute experiments in healthy, urethane anesthetized rats. We first characterized neuronal responses to natural stimulation (brush, press, pinch, crush) and electrical stimulation of the sciatic nerve. We then quantified the responses of isolated projection neurons during 20 s periods of SCS at frequencies from 10 Hz to 150 Hz with and without simultaneous ipsilateral sciatic nerve stimulation at amplitudes sufficient to activate both A- and C- fibers. Neuron responses to SCS could be characterized as excitation (increase in average firing rate during SCS), no effect, or inhibition (reduction in average firing rate during SCS). As predicted by the model, a subset of recorded neurons exhibited SCS frequency dependent inhibition. The new understanding resulting from the model and experimental studies provided important insights to guide the design of novel methods of stimulation. An entirely new dimension of neural stimulation parameters – the timing between stimulation pulses – may increase the efficacy and efficiency of spinal cord stimulation. For more information, please contact Cheryl Dudek at (216) 231-3257.

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