CLOSED LOOP SPINAL CORD STIMULATION
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Introduction

Despite the long term clinical success of spinal cord stimulation for the relief of neuropathic pain both mechanisms of action and strategies for rational design of stimulation systems and paradigms have so far evaded the technical and scientific neuromodulation community. We have developed new tools for in-situ study of the electrophysiology of neuromodulation via measurement of the electrically evoked compound action potentials (ECAPs). We have used data obtained from both animals and humans to study the excitability and properties of spinal dorsal column fibers. This understanding has allowed us to develop a closed loop neuromodulation control system that continuously adjusts the stimulation parameters to maintain constant dorsal column recruitment. The amplitude of the stimulation is only one of many factors that need to be adjusted to obtain optimal patient outcomes. Stimulation frequency is another. A study of the dynamic response of dorsal column fibers via ECAP recording may provide an indication of optimal stimulation frequency ranges.

Materials and Methods

Animal studies were conducted with anesthetized sheep and a variety of standard and custom made electrodes. Trial SCS leads were implanted in human subjects and connected to a custom built recording and stimulation system (Saluda Medical). A large variety of pulse parameters were studied including dynamic parameter control where the ECAP amplitude is used to continually adjust the stimulation currents. To study the effects of stimulation frequency on recruitment of dorsal column fibres number of multi pulse paradigms (from 2 pulses to several hundred) a variety of frequencies and amplitudes were used and responses recorded.

Results

The ECAP recording and stimulating system is able to dynamically adjust the amplitude of the stimulation current and maintain constant neural recruitment even for intrinsic motion due heart beat and breathing but also for sudden motion eg coughs. Paired pulse experiments in humans and the sheep model were used to determine the refractory period of dorsal column fibres and this was found to be ~500 microseconds. A model was developed based on the refractory period which is able to predict the amplitude of the ECAP up to high stimulation frequencies.

Conclusions

Closed loop control of amplitude provides significant improvements over conventional stimulation for maintenance of dorsal column recruitment with conventional stimulation frequencies (30 – 150Hz). Dorsal column recruitment at high frequencies (up to 11kHz) has been measured and explained by simple models which are consistent with the clinic observation that the paraesthesia threshold is constant with increases in stimulation frequency.

AUTHORS
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REFERENCES
