Introduction

Intrusion of an epidural catheter with electrodes for electrical spinal cord stimulation (SCS) became a clinical method for modification of lumbar cord motor activity in seventies of the past century. The implant generates an electrical field that stimulates the posterior structures of the spinal cord. The procedure involved a mechanical method for modification of motor control in subjects suffering from upper motor neuron disorders (e.g. multiple sclerosis, cerebral palsy, stroke or head and spinal cord injury). Applying SCS for suppression of spasticity in subjects with paralyses lead to the observation that the effectiveness depends from the site, strength and frequency of stimulation. Furthermore, a particular range of frequency on the same site of the lumbar cord and unchanged strength can elicit a variety of features of motor outputs as shown in the figure below.

Figure: EMG recordings of SCS at different frequencies in quadriceps (Q), hamstrings (H), triceps (TH) and tibialis anterior (TA).

The figure above illustrates that with a progressive increase of frequency the amplitude is steadily decreased and the complexity increased. Such EMG recordings during SCS consist solely of stimulus-time locked compound muscle action potentials. Our hypothesis is that the dynamics of these stimulus-time locked responses should reveal information about the configurations of the lumbar cord motor network. Thus we analyzed the dynamics of the peak-to-peak amplitude and the shape of the responses. This was implemented defining categories and analyzing the frequency of their occurrence at different stimulation frequencies and in different muscle groups.

Stimulation and recording

The data was collected during the clinical protocol for evaluating the optimal site and parameters of the epidural space. The impedance was generally about 1 kΩ. The local ethics committee approved the clinical protocol. All subjects gave informed consent. The data was collected during the clinical protocol for evaluating the optimal site and parameters of the epidural space. The impedance was generally about 1 kΩ. The local ethics committee approved the clinical protocol. All subjects gave informed consent.

Categories: dynamics of response amplitudes

Amplitudes of the single responses are defined as the difference between the maximal positive and maximal negative deflection from zero in the time window between two stimulation pulses. The data analysis has been conducted in MATLAB (Mathworks Inc., Natick, MA, USA). Based on manual observation of the recordings a sequence of 4 categories depending on the change of amplitudes over time was identified. The motor unit activity recorded by sEMG from paralyzed lower limbs, evoked by intradural electrical stimulation (SCS) became a clinical method for modification of lumbar cord motor activity in seventies of the past century. The implant generates an electrical field that stimulates the posterior structures of the spinal cord. The procedure involved a mechanical method for modification of motor control in subjects suffering from upper motor neuron disorders (e.g. multiple sclerosis, cerebral palsy, stroke or head and spinal cord injury). Applying SCS for suppression of spasticity in subjects with paralyses lead to the observation that the effectiveness depends from the site, strength and frequency of stimulation. Furthermore, a particular range of frequency on the same site of the lumbar cord and unchanged strength can elicit a variety of features of motor outputs as shown in the figure below.

Figure: Examples of the three categories of the dynamic changes of the shape of the stimulus-time locked responses during a 10 s recording. All three responses are shown as successfully evoked motor unit responses triggered at 5 s of a 10 s sample of the recording. The shape is constant over the time of the recording (quadriceps at 10 Hz). The lower figure shows an example of change in time for right and left triceps surae and at the paraspinal trunk muscles. Silver-silver chloride surface electrodes were used. The biopolar recordings were plotted in the demarcated stimulus space. The impulse was generally about 1 μA. Bipolar stimulation pulses were applied. The first phase was 100 μs and the second phase was used to balance the shape.

Categorisation: dynamics of response amplitudes

The categories of amplitudes and shape of motor units are a result of differences in geometry of stimulation and partially due to diverse configuration of motor units. In conclusion, the human lumbar cord deprived of brain motor control can produce a variety of classes of complex output patterns that depend on the stimulation frequency.

References


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Note: The figure illustrates part of the data listed in the table.

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