Selective Activation of Sciatic Nerve using Magnetic Microcoils - A Simulation Study

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Sciatic nerve of mammalian animals is a multifascicular structure in which different motor/sensory fibers are grouped together depending on their end connections to the individual muscles. Therefore, to create complex muscular movement, the peripheral nervous system (PNS) activates (synchronously/ asynchronously) motor fiber groups associated with different muscles. The lack of PNS connectivity to muscles (due to nerve or motor cortex damage) can be alleviated by electrical stimulation [Yale J 2012]. Multichannel cuff electrodes have been used to selectively activate different regions inside the sciatic nerve [A. Choi *et al.* 2015]; however, due to the significant heterogeneity of the nerve and surrounding media, this solution presents various challenges. In fact, this can result in significant high stimulation threshold (injected current) and potential nerve damage. Recently, magnetic stimulation of peripheral nerves has shown numerous advantages over electrical stimulation by achieving contactless neural activation [A. K. RamRakhyani *et al.* 2015]. Compared to non-penetrating cuff electrodes which requires the stimulation current to flow through low conductive nerve membrane (sigma = 0.02 S/m) and perineurium (sigma = 0.01 S/m), magnetic coil induces eddy currents directly inside the intracellular space of individual nerve fiber, thereby achieving contactless neural activation.

In this work, we have performed a simulation study to cause selective activation of the individual fascicle and motor fiber group inside the rat sciatic nerve. To control the induced field distribution inside the nerve, an array of magnetic microcoils are distributed around the circumference of the sciatic nerve. Using four solenoid shaped microcoils (outer diameter 2 mm) positioned perpendicularly to the nerve (diameter 1 mm), the total stimulator dimension was limited to 5 mm x 5 mm x 2 mm. In this neural stimulator, desired activation region and eddy current profile was selected by the controlling magnitude and direction of the current in individual magnetic coils. To simulate the induced electric field distribution inside a realistic tissue environment, a 3-dimensional heterogeneous nerve model of the rat sciatic nerve was created using the histological cross sectional image with the preservation of different tissue (i.e., nerve membrane, epineurium, perineurium, extracellular and intracellular space) and tissue boundaries. For the induced field stimulation, electric field contribution from individual coils were calculated using the Impedance Method [A. K. RamRakhyani *et al.* 2015, N. Orcutt *et al.* 1988] and weighted effectively to cause selective activation inside the fascicles. This work also includes multiple field profiles as the function of different coil current contributions.