Use of Impedance Method to Study the Efficacy of Magnetic Stimulation in Feline Sciatic Nerve

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Recently, magnetic stimulation of the central and peripheral nervous systems is becoming an alternative mechanism to the electrical stimulation. Due to the excellent permeability of the magnetic fields in tissue, magnetic stimulation is found as a non-invasive or minimally invasive technique that can increase the efficacy and longevity of the neural stimulator. Magnetic stimulation, as compared to electrical stimulation, uses alternative current in the magnetic coil to induce eddy currents in conductive tissues to elicit a neural response. Traditionally, analytical solutions have been pursued to understand the underlying mechanism of magnetic stimulation incorporating simple nerve/tissue models [1-2]. Few attempts were also taken to study the effect of tissue boundaries on the induced electric field [3]. However, due to the overly simplistic tissue models, these analytical solutions did not provide sufficient insights on the stimulation conditions for the neural response.

In general, peripheral nerves consist of different tissue types, including epineurium, perineurium, endoneurium, intracellular, and extracellular space. The conductivity of these materials ranges from 10^{-7} S/m to 1 S/m, creating wide discontinuity in conductivity at the medium boundaries. For a nerve bundle with thousands of fibers, the induced electric field can be greatly affected by the inhomogeneity of the conductive properties of the intracellular and extracellular space. To gain an understanding of the neural excitation in the presence of induced magnetic fields, we developed a computational model of the inhomogeneous nerve bundle including the effect of dielectric interfaces. Using the impedance method, we modeled the nerve bundle as a network of impedances to simulate the spatial variation of the induced electric field caused by the time-varying magnetic field.

In this work, an impedance method based network model as applied to the modeling of feline sciatic nerve is implemented. The feline's sciatic nerve consists of many fascicles and each fascicle is a bundle of hundreds of nerve fibers encapsulated by perineurum tissue. The developed nerve model incorporates the interface between different fascicles and myelinated nerve fibers inside each fascicle of the nerve. Our preliminary results show that, using the impedance method, transmembrane potential of individual nerve fiber can be simulated. By calculating the change in the transmembrane potential, individual nerve fiber that can be stimulated using magnetic fields are identified. Experimental validation of the computational results will also be presented.

[1] Roth, Bradley J. et. al. (1990), IEEE TBME, 37(6), 588-597.
[2] Nagarajan, S.S. et al. (1993), IEEE TBME, 40(11), 1175-1188.
[3] Nagarajan, S.S. et al. (1996), IEEE TBME, 43(3), 304-312.