Effect of Surrounding Conditions on *In-Vitro* Magnetic Neural Stimulation

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Over the last decade, magnetic stimulation based excitation of neural tissue has become an emerging technique for neuroprosthetic systems [1]. Unlike electrical stimulation that requires direct current injections into neural tissue, magnetic stimulation induces current in the central and/or peripheral nervous systems [2]. To better understand the mechanism of magnetic stimulation, we have used numerical modeling of the fields induced in the neural tissue and compared these results to observations from *in-vitro* experiments [3, 4]. The work reported in this paper is primarily motivated by the significant variation in stimulation threshold observed during these experiments [5]. In particular, we have found the induced electric field is greatly affected by the inhomogeneity in the conductive properties of the nerve and the surrounding medium. Here we report the effect of the surrounding media (Frog Ringer's Solution, FRS) and the magnetic coil's positioning on the stimulation threshold during *in-vitro* experiments.

To study the mechanism of magnetic stimulation and identify the key parameters affecting the stimulation threshold, we magnetically excited sciatic nerve from euthanized bullfrogs (*Rana catesbiana*). The sciatic (and the tibial nerve branch) was extracted from the spinal cord to the innervation of the gastrocnemius muscle. The nerve was placed in a plastic Petri dish and the Achilles tendon was suspended vertically to a force transducer. Additionally, we inserted two fine wire electrodes into the gastrocnemius muscle to record the electromyogram (EMG). Both figure-8 and solenoid magnetic coils were fabricated and were used to induce an electric field. Coils were driven with an in-house designed magnetic stimulator that can source up to 420 V across the coil. These coils were placed under the Petri dish to assure electrical isolation. To study the effect of the surrounding conditions on the induced electric field, we controlled the volume of FRS in the Petri dish. In addition, we studied the effect of the coil's position by shifting the coil's placement location along the nerve.

Using a figure-8 coil (diameter 32 mm), the stimulation threshold was 207 V with the nerve completely submerged in the conductive media (FRS). By reducing the solution's volume by 30 %, the threshold increased by 48 % to 307 V. With no FRS in the Petri dish, the stimulation threshold was above 420 V. Numerical simulations in the presence of the inhomogeneous medium, consisting of nerve bundle and FRS, predicted that the induced electric field strength is reduced with the reduction of solution height with respect to nerve diameter, which agrees with the experimental observations. To study the effect of the position of the coil with respect to the severed end of the nerve, the peak of the electric field produced by the figure-8 coil was aligned along the nerve; the minimum stimulation threshold was found when the peak induced electric field was 5 mm away from the nerve end and was close to the gastrocnemius muscle. Similar observations were made for the solenoid coil. Numerical simulation of the steady state transmembrane potential confirms this observation.

In this work, we studied two key parameters of *in-vitro* stimulation which can significantly affect the stimulation threshold. The observations from the experiments are in good agreement with the numerical models and show that threshold prediction for the magnetic stimulation requires generalized computational models to represent different stimulation conditions. As a future work, we intend to utilize these models along with active nerve models for accurate prediction of the stimulus threshold.

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