Feasibility studies of Micro-TMS in Neurostimulation.
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Introduction: Micro-magnetic stimulation (μMS) is an emerging technology with a great promise to revolutionize therapeutic stimulation of the human nervous system. Originally developed to single stimulation neurons (see ref), μMS uses ultra-conductive neuron-size coils that are capable of carrying current pulses large enough to elicit neural activation by means of magnetic induction. Depending on their dimension, μMS probes are capable of inducing neuronal activation in small areas limited to a few hundred microns to a few millimeters, rendering the technology a unique tool for ultra-focal brain stimulation. Taking advantage of the latest advancements in micro-fabrication, we were able to manufacture highly-conductive long traces with cross-sections as small as a few square microns. In this study, we have performed electromagnetic (EM) simulations to study the induced E and B fields in the human head in order to estimate the optimal coil design and the amount of current necessary for neurostimulation.

Materials and Methods: The Finite Element Method (FEM) is being used to study power dissipation and the induced field inside and around the μTMS coils. The simulations were performed in Multiphysics 5.2 (COMSOL, Burlington MA) using realistic modeling electromagnetic field estimation. The geometry consisted of a toroidal coil of 15 mm diameter, which is placed on top of our human head model (HEMA). The FEM calculations were performed using the quasi-static magnetic field approximation (AC/DC module) inside a sphere with magnetic insulation boundary conditions (\( \mathbf{n} \times \mathbf{A} = 0 \), where A is the magnetic potential and \( \mathbf{n} \) is the normal). The coil are driven with 75A currents and have a total of 492 turns, which is consistent to our prototype (Fig).

Results and Discussion: The preliminary results show in the Fig that we can generate B-fields strength of 2.5 Tesla using μTMS coils. This type of EM simulations will allow us to optimize coil design and strength for neuromodulation. Moreover, because of their ultra-small size, will allow integrating μTMS elements in multi-channel whole-head conformal arrays that will fit in a human head size helmet, enabling for the first time, the simultaneous multifocal stimulation of the human brain.

Translational Impact: μTMS has the potential of a transformative impact on the applicability of non-invasive brain stimulation, as it allows for a well-controlled stimulating and mapping of the human cortex with an unprecedented resolution.

Disclosure Statement: There are no conflicts of interest to declare in this study.

Acknowledgments: This work was conducted with support from National Institutes of Health Award R01MH111875.


Figure (Left) Image of the μTMS coil prototype built, and (right) FEM simulations result of the B-field generated inside the human head by an equivalent coil.