Low Frequency Magnetic Steering Helmet for Deep Brain Pathologies
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Introduction: Parkinson’s Disease (PD) is a neurodegenerative disorder that seems to be associated with a lack of dopaminergic neurons in the substantia nigra. Levodopa Drug Therapy is a typical PD treatment, but patients often develop resistance to the oral medication and can develop motor complications, such as levodopa induced dyskinesias (LID). Currently, the most successful treatment for PD is Deep Brain Stimulation (DBS), in which surgically implanted electrodes deliver an electrical current in a specific targeted area of the brain. While DBS is usually effective, the process remains very intrusive with surgical complications, and the efficacy of electrode-based implants is limited (1). DBS also requires constant clinical recalibration of its stimulation parameters as the disease progresses. Additionally, the integrity of the device hosted in biological tissue is at risk of deleterious effects due to scan exposures, hardware wear and tear and lead fractures as a result of inappropriate location of extension cables. The Magnetic Steering Helmet (MSH) is a proposed solution to developing a wearable, non-invasive, deep brain stimulation device that uses magnetic stimulation to treat refractory brain disorders. The goal of MSH is to relieve symptoms of deep brain pathologies, mainly Parkinson’s Disease (PD), through the modulation/calibration of neural activity. Also, it will be designed to be lightweight, portable, and convenient to use.

Materials and Methods: Simulations were run on Sim4Life, a multiphysics solver with computable human phantoms, to model the magnetic fields produced by the helmet inside the MIDA computer model. MIDA is a “Multimodal Imaging-Based Detailed Anatomical Model of the Human Head and Neck” which provides morphological and electromagnetic properties of different brain layers and delineates 153 macroscopic brain structures (2). A hemispherical coil array with 35 coils was modeled around the MIDA model, as shown in Figure 1 to direct magnetic beams towards the center of the head. Each of the 35 coils was stimulated at 10 mA at 2.0 kHz. Coils were modeled as solenoids with the following parameters: 200 turns, AWG 24, copper wiring, and a coil radius of 5 mm. The simulation was run using Sim4Life’s electromagnetic quasi static solver.

Results and Discussion: The signals from left and right-hand sides are differed by a frequency in the range of 10-50 Hz. The result is a centered envelope over the carrier waves with frequency equal to the difference in carrier wave frequencies. The magnetic field strength decays as expected, but fairly significant fields are present at the center of the brain as intended. The magnitude of the H-field at the center of the brain was approximately 0.45 A/m. The penetration of the field into the deep brain is a good proof of concept that we can target basal ganglia structures, which are compromised in PD. Figure 1 shows the field reaching Deep Brain structures such as the Thalamus and Globus Pallidus.

Translational Impact: It was found that interferential stimulation with two sinusoids at 2.01 KHz and 2 KHz, resulting in a Δf envelope frequency of 10 Hz, was able to recruit neurons to fire at 10 Hz, as effectively as direct 10 Hz stimulation, which would be expected to broadly affect neural activity (3). This along with the simulations presented here suggest that the stimulation of the deep brain is feasible with this type of noninvasive design. Most available TMS (transcranial magnetic stimulation) devices can only reach cortical layers. Future studies may focus on hyper-tuning parameters for improved results, creating the physical helmet, and developing modifications to target other neuropsychiatric diseases and disorders.

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