A novel approach for EM dosimetry applied to the neuronavigated TMS: the En-TMS

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TMS has been extensively used over the years as a therapy for several psychological and neurological disorders [1], as well as a diagnostic and neuro-investigational tool, for example in presurgical-mapping applications [2]. In this context, a crucial issue is the correct position of the TMS coil over the target brain area. Currently, a new technique, known as navigated (n-)TMS, has been developed, and makes use of optical trackers combined with MRI scans to ensure an accurate position of the stimulating coil over a patient's brain [2]. Furthermore, localization of the stimulation spot on the subject's head can be obtained by computing and visualizing the induced electric (E-)field on the surface of the cortex [2]. Thus, an accurate modeling is necessary for such application.

In this work we present a novel nTMS approach, called the Effective navigated (En-)TMS, able to manage high-resolution patient specific head models with anistropic brain tissues, obtained from MRI and DTI data, to accurately calculate the induced E-field with the aim to provide a precise location for the stimulation spot in TMS applications. The software for EM dosimetry is written in the C++ environment and implements the admittance method [4]. The stimulating coil is modeled through its magnetic vector potential **A**, computed off-line prior to any application. Whereas the head model is reconstructed as a mesh of 3D voxels, obtained from MRI derived geometrical and anatomical information. The dielectric properties of the isotropic tissues of the head are assigned from the LF IT'IS database [4]. Whereas the brain tissues of grey (GM) and white (WM) matter are modelled as inhomogeneous anisotropic tissues, with each voxel described by its own conductivity tensor obtained from the DTI data. To test the developed software, a 4-tissues model was obtained from the MRI scans of a healthy subject that underwent a session of TMS stimulation. The model included the scalp (σ=0.465 S/m), the CSF (σ=1.78 S/m), the GM (inhomogeneous and anisotropic) and the WM (inhomogeneous and anisotropic). By retrieving the relative position between the coil and the head from the optical tracking system used during the TMS session, the coil model was properly placed over the motor area (M1), 45° tilted with respect to the interhemispheric scissure, and then was rotated in clockwise and counterclockwise directions, by ±10°, ±20°, and ±40°. The current flowing through the coil was a 3 kHz sinusoid with amplitude equal to 3.7 kA, corresponding to the stimulation intensity when working at the subject's motor threshold. The E-field distribution was estimated for each coil rotation. Results showed that the coil orientation strongly influenced the location of the maximum E-field, that would shift up to 1 cm in the posterior-anterior direction for the -40° and -20° degrees rotations, causing stimulation of areas other than the target one. Focusing on M1, the maximum E-field intensity was induced by the coil placed at the reference position (i.e., 112 V/m). These results suggested that such novel software would be able to guide the coil placement in order to maximize the TMS stimulation, in virtue of considering an accurate modeling of the head that includes the anisotropic properties of the brain.

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