Numerical Computation of the TMS-Induced Electric Field in Rat Brain

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Repetitive Transcranial Magnetic Stimulation (rTMS) is a non-invasive neuromodulatory technique, using time-varying magnetic fields, to study neural networks organization for both diagnostic and therapeutic purposes in several neuronal and psychiatric disorders [1].

Recently, the potential therapeutic role of rTMS in Parkinson's disease has been investigated both on human subjects and animal models, showing that acute rTMS treatment was able to produce an increase in dopamine content in subcortical regions [2]-[3] and induce temporary plasticity in target areas [4]-[5].

Studies on small animals generally use the same instrumentation, i.e. coil and stimulator, used in clinical applications and suffer from the need to extrapolate the stimulation parameters from humans to another species. Indeed, the great difference in size between a human head and a small rodent's head may cause considerably different stimulation conditions of neuronal structures. Therefore, in this study we want to quantify the electric (E) field induced in the brain areas of a rat during acute exposure to an intermittent Theta-Burst Stimulation (iTBS) session as described in [3]. The final aim is to contribute to the definition of a dose-response relationship and, eventually, to the improvement of the experimental protocols.

This dosimetric study was performed using the commercial software Sim4Life (v.5, Zurich MedTec, Zurich). The chosen animal model was the ViZOO big male rat [6] (260 mm of length; 567 g of weight), since it better described the male Wistar rats used in [3]. The model included 51 different tissues, whose permittivity and conductivity were taken from the IT'IS database [7] at 3 kHz. Being a posable model, the rat's position was modified to have the head as parallel as possible to the plane of a figure-8 coil (175×88 mm^2; 2×9 windings), placed over the bregma, at 13 mm from the scalp, to mimic the experimental conditions. Current flowing in the coil (I=3.7 kA) corresponded to the 30% of the maximum output set on the stimulator, accordingly to [3]. Simulations were carried out by solving the quasi-static module with a spatial resolution of 1 mm. The average (E_{mean}) and the maximum (E_{max}) E fields were calculated and compared, specifically in the brain structures included in the rat model: cerebrum, midbrain and cerebellum. E_{max} was estimated by means of the 99.9th percentile.

Looking at the E-field distribution in the whole animal, one can see that, despite the big size of the coil with respect to the rat, the head is considerably more exposed than the rest of the body. For what concerns the brain regions, the most exposed ones are the cerebrum (E_{max}=90.2 V/m; E_{mean}=42.4 V/m) and the midbrain (E_{max}=92.2 V/m; E_{mean}=33.6 V/m). The higher value of E_{mean} calculated in the cerebrum reveals that it is exposed more uniformly than the midbrain. Even the cerebellum exhibits considerable E-field values (E_{max}=72.3 V/m; E_{mean}=27.1 V/m), comparable to those obtained in the stimulation of motor cortex in humans, of the order of 80-100 V/m [8].

These preliminary results reinforce the experimental outcomes of [3] and suggest that an accurate iTBS dosimetry can support the experimental activity in the identification of possible interaction mechanisms and the definition of stimulation protocols.

Further studies will assess the sensitivity of such results with respect to possible sources of uncertainty, such as a mismatch in the coil positioning and changes in the tissues properties or in the spatial resolution.

References

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