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The Impact of Brain Anatomy on TMS-Induced E-Field Distribution

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Extended Abstract

Transcranial magnetic stimulation (TMS) is a non-invasive brain stimulation technique [1] that is being increasingly employed for diagnostic and therapeutic purposes in multiple neuropsychiatric conditions [2]. In order to predict or interpret biological outcomes of clinical TMS interventions, the method is often combined with electric field (EF) modeling [3], i.e. the numerical calculation of the induced EF distribution in the brain, usually computed on the subject's head model. The main objective of the present study was to investigate the impact of anatomy on brain stimulation during TMS, on healthy male and female adults.

The human anatomy can affect the EF distribution, and subsequently influence the outcome of TMS, in two separate ways, i.e. due to individual morphometric characteristics, such as the shape and size of brain, or due to the tissue distribution inside the head. To disentangle these two factors, we examined the EFs, induced by an H7 Hesed coil (Brainsway Ltd., Israel) [4], on anatomical and homogeneous head models of nineteen volunteers (7 males, 12 females). The former were generated through an automatic segmentation process by the headreco tool of the SimNIBS software package (SimNIBS Developers. SimNIBS 3.2.4), using the participants' MRI data, after obtaining informed consent. The corresponding homogeneous models were then created from the anatomical ones, by assigning to all their tissues the electrical conductivity of saline. All head models were stimulated by the H7 coil placed over the frontal lobes, in the Sim4Life environment (ZMT Zurich MedTech. Sim4Life), employing the platform's magnetic quasi-static solver, and assuming a current with an amplitude of 3.18 kA and a frequency of 3.5 kHz.

The numerically calculated EFs were compared, in terms of maximum value (E_{max}), considering the 99^{th} percentile of distribution as E_{max} to avoid numerical artefacts, and half-value volume ($V_{1/2}$), i.e. the volume of brain where the EF was greater than the half of its E_{max}, among different groups. Analysis showed that the maximum EF on the male sample was around 187.3 ± 7.9 V/m for the anatomical versions and around 133.2 ± 6.5 V/m for their homogeneous duplicates, while the corresponding half-value volumes were 56.5 ± 10.0 cm^3 versus 102.5 ± 12.4 cm^3. Regarding the female sample, the EF distributions on anatomical models showed maximum values around 192.3 ± 13.4 V/m versus 135.9 ± 9.6 V/m for the homogeneous ones, while the half-value volumes ranged around 57.4 ± 7.2 cm^3 against 104.6 ± 19.2 cm^3, respectively. Results showed higher values and dispersion for the E_{max} metric on anatomical models of both samples, while the standard deviation for the homogeneous female group was more than two times higher than the one for the anatomical female group. As expected, the half-value volumes were higher for the homogeneous models. Comparisons among subjects' distributions in every group, even for the homogeneous versions, imply that anatomical features may affect the stimulation outcome.

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