Modeling the Electric Field Distribution within the Brain for the Treatment of Glioblastomas

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PURPOSE

Oscillating electric fields are being investigated as an adjunct and even an alternative to chemotherapy in the treatment of glioblastoma multiforme (GBM)[1]. The magnitude and direction of the electric field in the tumor are important determinants of treatment efficacy[2]. Here we used a realistic head model constructed from MRI data to calculate the electric field distribution in the brain during the application of tumor treating fields (TTF).

METHODS

A realistically shaped head model was created from MRIs with a voxel size of 1x1x1 mm^3. Images were segmented into five different tissue types: scalp, skull, cerebrospinal fluid (CSF), gray matter (GM), and white matter (WM). Two pairs of electrode arrays were placed on the scalp, as in the Novocure system (http://www.novocure.com). Each electrode array consisted of nine interconnected electrodes, capacitively coupled to the scalp. A volume mesh was then generated and used to calculate the electric field using the finite element method (FEM). The tissues were assumed to be isotropic and values for their dielectric properties were taken from the literature for each tissue type. The frequency of the impressed current was set to 200 kHz; the amplitude of the current through each electrode in each array was set to 100 mA.

RESULTS

The resultant electric field was calculated for two electrode configurations. In the first one, the electrode arrays on the left and on the right of the subject's head (see Figure 1a) were activated, in the second the anterior and posterior arrays were activated. In both cases, the magnitude of the electric field exceeded 1 V/cm over large areas of the brain. The magnitude of the electric field is higher in the WM (Figure 1b,c) because its impedance is higher than that of GM. The low impedance of the CSF in the ventricles also affects the electric field in the nearby brain tissue.

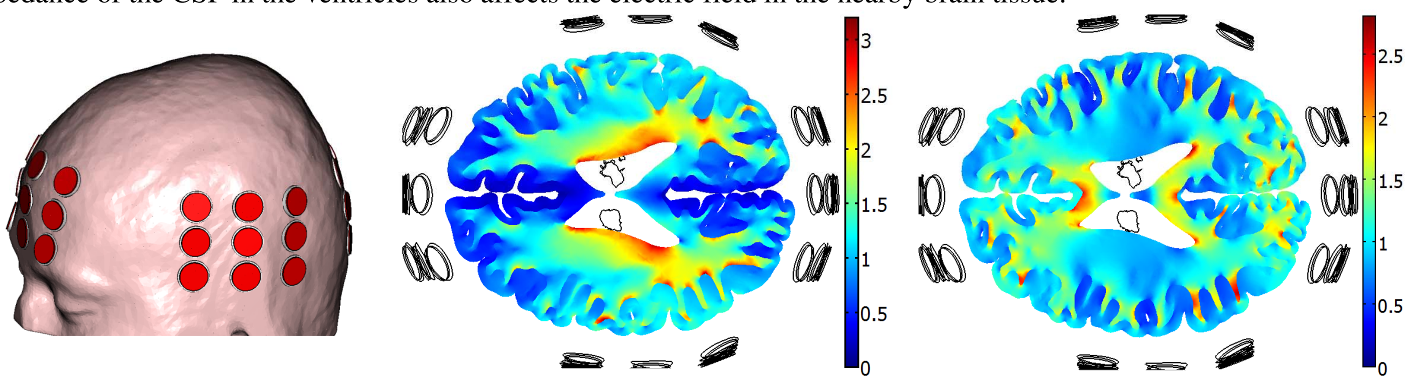

Figure 1: (a) The head model with 2 electrode arrays clearly visible. (b) The magnitude of the electric field (V/cm) in the brain when the left-right electrode arrays are activated; and (c) when the anterior-posterior arrays are activated.

DISCUSSION

These FEM calculations indicate that the electric field magnitude predicted in the brain is sufficiently high to arrest cell proliferation based upon *in vitro* experiments[2]. However, the electric field is not uniform as it is affected by the distribution of tissue types, the location and orientation of interfaces between them, and their individual electrical properties. As a result of tissue heterogeneity, shunting as well as concentration of current and electric field can be observed in different parts of the brain. The inclusion of anisotropy in the electrical conductivity of white matter in future models is expected to increase the observed shunting and spatial non-uniformity of the tumor treating electric fields.

CONCLUSION

Patient specific FEM models based upon MRI data could provide a means to estimate the electric field in the tumor and to optimize its delivery. This new tool could be used in treatment planning, and for understanding outcomes of TTF therapy.

REFERENCES:

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