In silico electromagnetic simulation of a murine glioma model at 7T MRI conditions

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Introduction: Changes of dielectric properties in tissues under radiofrequency excitation result in variations of specific energy absorption (SAR) values that might translate into excessive heating in strong electromagnetic environments. Conductivities of glioma tissue exceed normal brain conductivities by a factor of two [1, 2]. Electromagnetic modeling is a valuable tool to simulate tissue response to stimuli such as that of MR methods. The combination of available information for tissue dielectric properties, animal model anatomy, and MRI system characteristics can be successfully implemented *in silico* with the purpose of preclinical experimental planning. This study illustrates the analysis of several scenarios regarding a murine glioma animal study that are relevant to translation into the clinic.

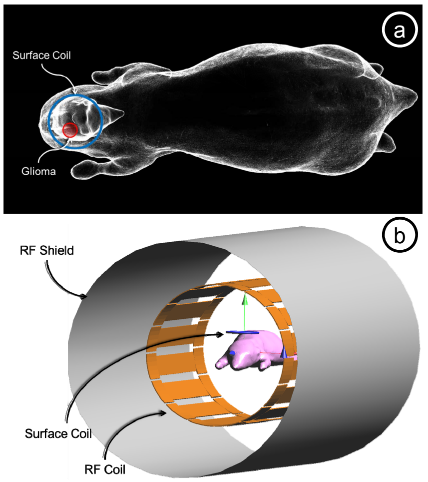

Figure 1. General geometry of the electromagnetic model. (a) Shows the geometry of the mouse mesh including the brain, a glioma tumor, and the position of the surface coil. (b) Shows the location of the mouse model inside the RF Coil.

Methods: The mouse geometry was re-segmented from the CT/histological mouse atlas [3] from the University of Southern California (Figure 1a) using iSeg (ZMT Zurich MedTech AG, Zürich, Switzerland). The meshes were imported into SEMCAD X 14.6 (Schmid & Partner Engineering AG, Zürich, Switzerland), and a sphere resembling a glioma tumor in the brain was added to the geometry. Refer to Figure 1(a). The Penn State birdcage coil builder [4] included in SEMCAD X was used to reproduce a 72mm quadrature RF Coil used in a 7T Preclinical MRI system (Agilent Technologies, Palo Alto, CA, USA) with RF pulse frequency at 300MHz. A graphical representation of the modeled Agilent coil is shown in Figure 1(b). A finite-difference time-domain (FDTD) solver included in SEMCAD X was used to solve the propagation and interaction of electromagnetic RF pulses with the mouse model at 300MHz. Dielectric characteristics were used from available published values for brain tissue and glioma conductivity [1, 2] from MR conductivity studies at 7T. Conductivities used for tissues were: Brain = 0.6 S/m, Glioma = 1.0 S/m, and other tissues = 0.4 S/m. The distribution of B fields at the head of the *in silico* mouse had inhomogeneity of less than 5%. The effect of the actively decoupled surface coil for the geometry and various parameters was studied. B field and E field solutions were extracted for the head, brain and the tumor. Corresponding values for conductivity density (J) and SAR were computed and normalized using the software.

Results: Higher tumor conductivity resulted in lower electric field intensity (E), higher current density (J), and higher SAR at the tumor site. While the E field intensity was lower, the influence of higher tumor conductivity is enough to increase J. This increase is linear and expected by $J=\sigma E$. Higher tumor conductivity also causes higher SAR values event though the E field is squared for SAR calculations. The actively decoupled surface coil included in the model resulted in lower incident fields on the head of the mouse. An extraction of results for a volume of interest can be seen graphically in Figure 2. These results also show that for the specific geometry and position of the surface coil, the coil has a dampening effect with respect to the incident fields. Thus, for the case including the surface coil, all values for E, J, and SAR are lower.

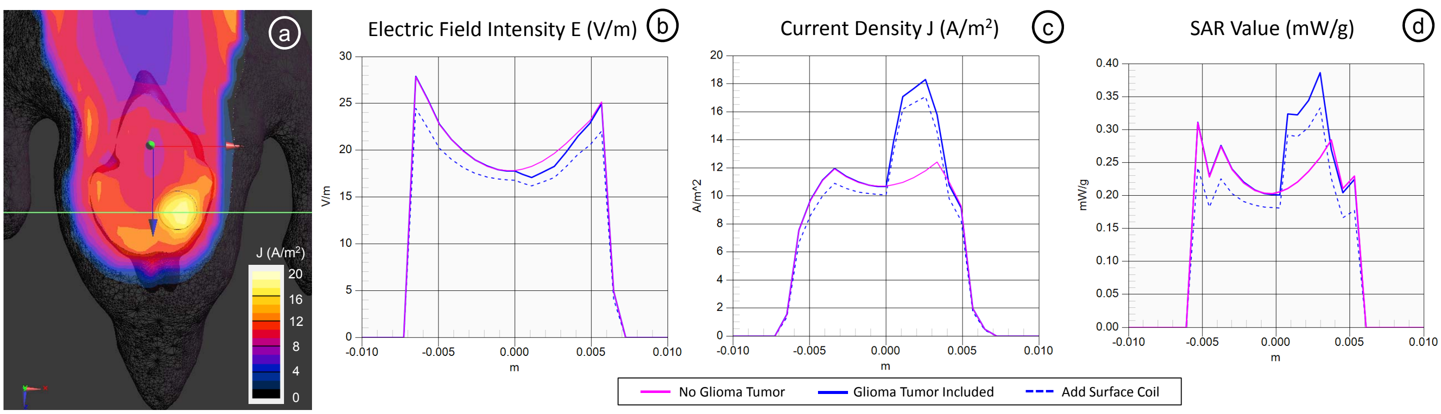

Figure 2. Results from electromagnetic simulation. (a) Shows a plane cutting thorough the glioma tumor and the resulting current density values. (b, c, and d) Show E field intensity, resulting J field density, and SAR values respectively, for three different cases. The case in which there is no glioma tumor is represented by the purple curves. The case for the tumor is represented by the blue curves, and the results from the addition of the surface coil are represented by the dotted blue curves.

Discussion: The present computational model and simulations studied the influence of tissue conductivites on induced electric field, current field and SAR distributions in a mouse head resulting from RF pulses of a 7T MRI system. While higher tissue conductivity results in lower electric field intensity, the former is responsible for increased electric currents and resulting SAR. Safety considerations must be taken into account regarding tissues surrounding gliomas. In the case of thermal effects due to energy absorption, tissues with distinctive vascularity such as tumors, must be modeled accordingly. Future comparative experiments that combine *in silico* modeling with *in vivo* measurements will be used to translate MR methods into clinical studies.

References:

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