MR Safety of Implants: Numerical assessment of SAR distribution at design-simplified stents of different lengths placed inside a virtual phantom model investigated at an MR frequency of 63.9 MHz

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OBJECTIVE

In respect of imaging quality and patient safety, temperature rises and SAR distributions, which are caused by interaction of the applied electromagnetic fields during MR exams, are of high interest for implants in MR tomography [1]. High local SAR values are equivalent to high local temperature increases [2]. For developing support for radio frequency (RF) induced heating experiments, SAR values were virtually investigated at design-simplified stents with different lengths inside a virtual human torso shaped phantom model

METHODS

5 design simplified stent models with different lengths (50-250 mm), but equal inner diameter (8 mm) and same material properties as well as same strut structure and thickness (0.8 mm) were modeled with SPEAG simulation software SEMCAD X. The stents were positioned at half 'gel depth' inside a virtual body phantom with geometrical dimensions described in ASTM standard F2182-02a [3] for experimental testing of RF induced heating of implants. The virtual phantom was filled with a medium ('gel') having an averaged conductivity of 0.47 S/m and dielectric property (ε_r = 81) of human tissue. The phantom was exposed to the electromagnetic environment generated by a virtual generic birdcage coil for investigating how the stent length and the imaging frequency affect the SAR distribution in the surrounding of the stents. The longitudinal axes of the stents were oriented parallel to the vector of the static main magnetic field B_0 and the electrical field. All stent and phantom configurations were investigated at the frequency (63.9 MHz) equivalent to a 1.5 Tesla MR system. The impact of different stent lengths on SAR distribution at a Larmor frequency is well-known. Its maximum SAR values are developing approximately at half wave length in 'tissue/gel'. The simulation and the theoretical results have been compared.

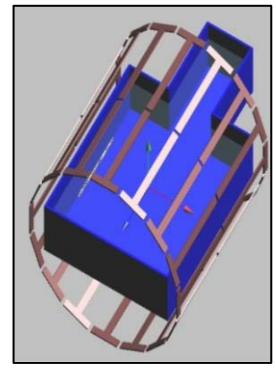

FIG. 1: Simulation setup

RESULTS

The results showed that each conductive loop of structure of a stents leads to higher local SAR values in the surrounding of the stent having a maximum effect for the stent lengths at half a wavelength in the specific conductive medium. However, the highest local SAR spatially occurred at the ends of the stents FIG. 2. The SAR is highly localized and its magnitude depends strongly on the stent length <u>and</u> on the frequency of the electromagnetic field in the specific conductive environment. Design-dependent effects, which could impact the RF induced heating, were not considered in this study because of design-simplified stent models.

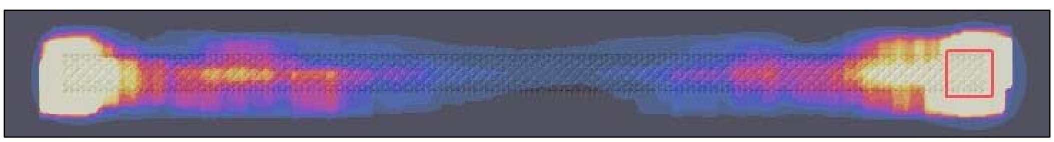

FIG. 2: Exemplary 1.5 T 1g avg. SAR distribution (linear scaling), design-simplified 200 mm stent

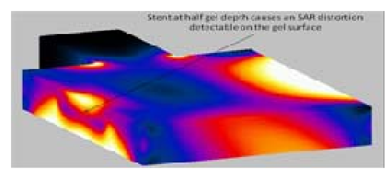

FIG. 3 1 gram averaged SAR surface field view (250 mm stent)

CONCLUSION

The relationship of RF induced heating is a multi-parameter dependent issue and basically related to parameters like the dimension of a conductive structure, the electromagnetic properties of the surrounding medium/tissue as well as the electromagnetic environment of the MR system including the MR transmit coil. The numerical investigation is very helpful in depicting the local SAR distribution at implants before performing experiments. Validation of numerical results and further research is necessary to establish computer modeling as a standard tool to support in RF heating testing of implants.

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