The effect of body size and shape on RF safety and B1 field homogeneity at 3T

B. van den Bergen[1], C. A. van den Berg[1], H. Kroeze[1], L. W. Bartels[2], J. J. Lagendijk[1]
[1]Dept. of Radiotherapy, University Medical Centre, Utrecht, Utrecht, Netherlands, [2]Dept. of Radiology, University Medical Centre, Utrecht, Utrecht, Netherlands

Introduction

Recent progress towards higher field MRI in clinical settings has drastically increased the number of safety related questions. Numerical electromagnetic field solvers have proven to be powerful tools to analyze these issues [1,2,3]. However, most studies are performed with only one patient model [1,2,3], ignoring the possible influence of anatomic differences. In this study we present some typical results about the effect of body size and shape on the B_1 field homogeneity and the creation of SAR (specific absorption rate) and temperature hotspots in a 3 Tesla MRI scanner.

Methods

For every patient in our hyperthermia treatment planning database we can simulate the electric and magnetic fields, the SAR deposition and the resulting temperature differences in the body during MRI imaging. The electromagnetic fields and their energy deposition are calculated with our *finite difference time domain* (FDTD) code and the resulting local temperature was calculated by numerically solving the Pennes - Bio Heat equation [4]. The resolution of our calculations was enhanced using a quasistatic zooming algorithm [5].

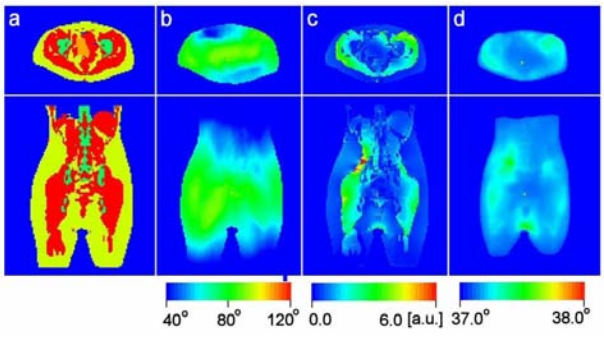

Figure 1, thin patient in 12 element TEM coil at 3T. Anatomy (a), flip angle (b), SAR [W/kg] (c), temperature (d).

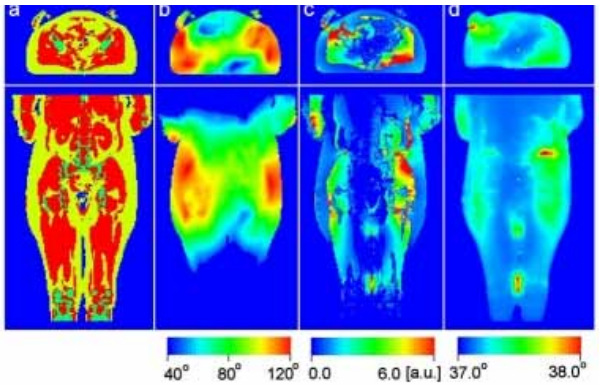

Figure 2, large patient in 12 element TEM coil at 3T. Anatomy (a), flip angle (b), SAR [W/kg] (c), temperature (d).

Results

Some typical results of our study are presented in *figures 1-4*. The effect of patient size is illustrated by comparing *figures 1* and *2*. The increased B_1 field inhomogeneity, the enhanced SAR deposition and the temperature raise for the larger patient are very distinct. These effects are believed to result from the fact that the body diameter exceeds the maximum distance over which the electric fields of the various antennas can have destructive interference. Imperfect destructive interference of the electric field at the outer parts of the body results in electric currents and SAR deposition.

Figure 3 demonstrates the influence of the patient 'shape' on the SAR deposition. On the right image the patient has created a closed loop between the upper legs. The left image is for the same patient, but with 1 layer of air voxels (5 mm) placed between the knees. The SAR hotspot due to the closed loop in the right image results in a relatively large temperature rise, as can be seen in *figure 2*.

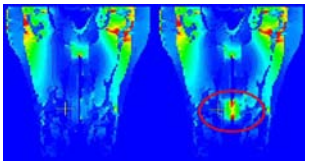

Figure 3, SAR with (right) and without (left) knees touching.

Figure 4 is an illustration of the quasi-static zooming program. It shows that at high resolution new hotspots can appear in comparison with a calculation at low resolution. Other calculations show that hotspots can also disappear when the resolution is increased, indicating that at low resolution hotspots can both be over- and underestimated depending on the underlying anatomy.

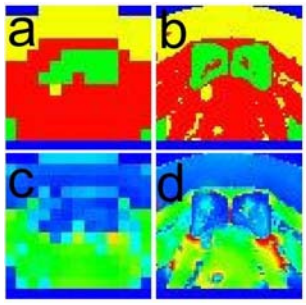

Figure 4, quasistatic zooming. low resolution anatomy (a) and SAR (c), high resolution anatomy (b) and SAR (d).

Conclusions

We have shown that the B_1 field homogeneity at 3T is dictated by the size of the body. SAR and temperature hotspot creation is affected by both the size and shape of the body and by anatomical details. It is necessary to use high resolution simulations such as quasistatic zooming to appreciate the full effects of the latter.

This study is useful for understanding RF induced anatomy effects on B_1 field homogeneity and local temperature behavior during MRI scanning. It can also serve to improve patient positioning and antenna steering protocols to obtain the optimum B_1 field homogeneity.

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