Obtaining patient specific RF field maps: Comparison of B1+ measurements and simulations for a human pelvis

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Introduction.

RF field non-uniformities and SAR deposition are one of the important challenges for the application of high field ($B_0 \geq 3$ T, $f \geq 128$ MHz) MR imaging. These issues have prompted the development of various parallel imaging and excitation techniques over the last years [1,2,3]. A central aspect in these techniques is to obtain information about the excitation (B_{1+}) and receive (B_{1-}) field in the patient. While at low field this information can be simply obtained by using the homogeneous field of the body coil as reference, this approach is no longer valid for high field MR. In this study, we compared two alternative techniques to obtain patient specific field information. In the first approach, an experimental B_{1+} mapping technique is used to acquire patient specific B_{1+} maps. In the second scheme the field maps were obtained by performing electromagnetic simulations on the same patient anatomy to obtain the field maps. Both techniques were already verified for cylindrical phantoms [4].

Method.

For this study, experiments were performed on a fresh human corpse that was treated according to university hospital ethical protocols. The human corpse was placed in a clinical 3.0 Tesla scanner (Achieva, Philips Medical Systems, Best, the Netherlands) using a quadrature driven body coil for excitation and reception. The B_{1+} field mapping technique consisted of a spoiled gradient echo sequence with a TR of 1500 ms and a TE of 2.5 ms. Ten images of the pelvis were collected equidistantly in a broad range of flip angles from 0 to 150 degrees. The in-plane resolution was 3 mm while a slice thickness of 10 mm was applied. Since the relatively short TR leads to T1-weighing in the images, a spatial T1 map had to be included into the analysis. An inversion recovery sequence was used to acquire such a T1 map. Fitting of the multi-flip angle data on a voxel-to-voxel basis to the equation for the gradient echo signal with inclusion of the spatial T1 map, results in the B_{1+} map [5].

A CT scan with a resolution of 1x1x3 mm was made of the human corpse just before the MR scanning. CT scanning has the advantage that by simple thresholding the image into dielectrically the most significant tissue types (bone, fat, muscle, inner air), a detailed dielectric model can be generated. It was refined by manually defining the bladder and the rectum. The dielectric model was placed into a model of a 3 Tesla body coil. The Finite Difference Time Domain (FDTD) method was used to calculate the magnetic and electric field inside the dielectric model of the human corpse [4]. The FDTD simulations were performed at an isotropic resolution of 5 mm.

Results.

The CT scan and the accompanying dielectric model of the human corpse are depicted in Figure 1a and 1b. Unfortunately, body decomposition processes lead to the presence of some air pockets inside the anatomy. However, they were both present in the MR and the CT scan. Figure 1c and 1d show an example of a simulated and the measured B_{1+} distribution taken at the same anatomical location. As can be seen, we obtained a good correlation between simulations and experiments. The measurements show some finer details such as a circular pattern in the hip joint.

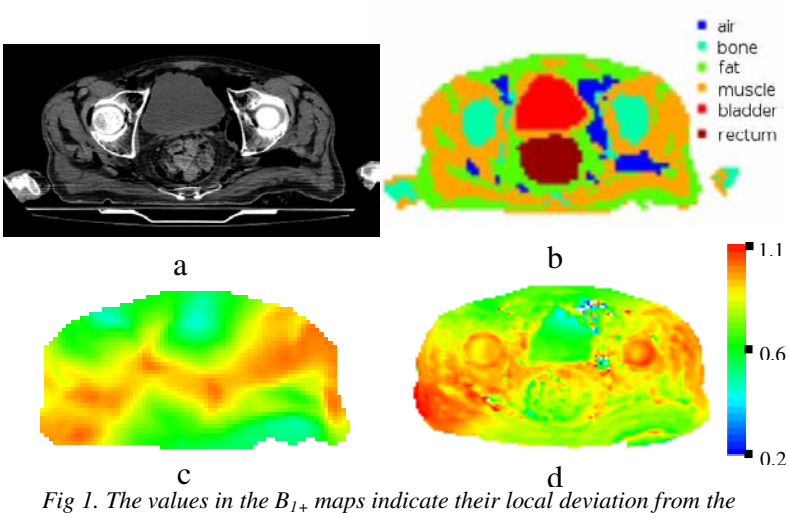

Fig 1. The values in the B_{1+} maps indicate their local deviation from the nominal (flip angle) setting.

Discussion and Conclusions.

Although the 5 mm isotropic resolution of the patient model is too coarse to sample the anatomy properly and resolve detailed B_{1+} variations, the global patterns matched the measured pattern closely. The B_{1+} distribution seems to be built up of a global pattern caused by the elliptical shape of the anatomy [6] plus a local anatomy-dependent part. This local term is correlated with discontinuities in tissue types such as observed in the hip joint. We will investigate whether these are due to measurement artifacts or caused by to local induced currents. For this last purpose, we will look into ways to increase the simulation resolution to obtain a more detailed description of the anatomy. However, we believe that the obtained match already validates our FDTD simulation approach.

The good match between the simulations and measurements also shows that both methods are capable of giving accurate information about the B_{1+} excitation field. Although the measurements show finer details, the simulation approach has the advantage of obtaining simultaneously information about the receive field and electrical field. The most important disadvantage of the simulations is of course that they consume too much time to be performed on-line. However, for parallel imaging purposes this is not a severe drawback, since image reconstruction can be performed off-line. A combination of both techniques might be therefore be a good candidate for obtaining field maps of a transceive coil array for parallel excitation and imaging at high field MR.

References:

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