Numerical Model of B0 Distribution in the Rat Brain

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INTRODUCTION: The differences in relative magnetic susceptibility (μ_r) between different tissues can result in the detection of important pathology and physiology with MRI, including iron concentration and the activation of areas in the brain during functional MRI (1). The differences in μ_r between tissues and air can also result in severe loss of signal and image distortions in MRI (2-3). Generally, MRI methods that are sensitive to the minor changes in the static magnetic field (B_0) that convey important information about the differences in tissue susceptibility are also easily adversely affected by stronger distortions in the B_0 field near air-tissue interfaces. Accurate models of the rat head with its many different tissue-specific susceptibility values could be useful in designing and evaluating engineering solutions to limit the severe field distortions at air-tissue interfaces, or at least limit their effects in the MR image, without eliminating the observation of minor distortions due to tissue-specific properties. Although attempts to model B_0 distortions in the human head have been presented previously (4), animal models are often used inT_2*-weighted sequences, such as for fMRI (5), and distortions in B_0 within these animal brains is rarely studied. Here we apply a numerical method previously developed for calculation of B_0 in the human head (4) to a numerical model of the adult rat.

METHODS: A finite-difference static magnetic field solver was developed using the concept of the magnetic vector potential (4). An MRI-based model of the adult rat was acquired from the USAF (http://www.brooks.af.mil/AFRL/HED/hedr) and adapted for static field calculations. The model had a resolution of 0.39 mm in all directions, though it is anatomically accurate only to about 2mm in the nose-tail direction. A course (2mm) 3D wire-mesh representation of the model is given in Figure 1. The B_0 field was simulated as being applied in the anterior-posterior direction (Fig. 1). Calculations were performed on a 400MHz PC and required about 12 hours for completion. Experimental images were acquired in an adult rat using a Bruker 3T imaging system and home-built gradient coil and birdcage coil sets (5). Images were acquired with a 256x256 matrix and 3cm x 3cm field of view, a 1mm slice thickness, and TE/TR=7ms/200ms and 37ms/200ms on a coronal plane approximately 7mm anterior to auditory canals.

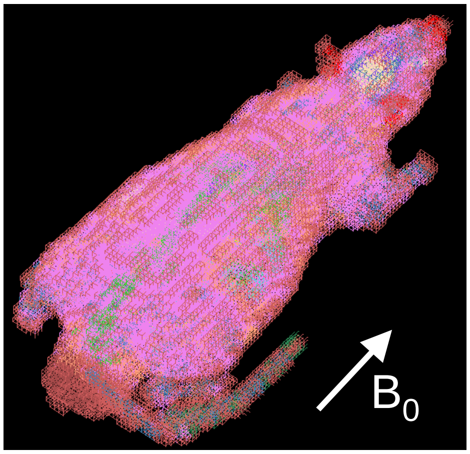

Figure 1: Coarse wire-mesh representation of 3D rat model showing direction of applied B_0

RESULTS: Experimental images and calculated B_0 field distribution on a corresponding coronal plane are given in Figures 2 and 3, respectively. With a TE of 37ms significant signal loss is seen in brain anterior to auditory canals. The calculated B_0 distribution shows that this is due to significant B_0 distortion and gradients resulting from the proximity to the auditory canals.

DISCUSSION: This work represents a first attempt to model the B_0 distribution in the adult rat brain in a three-dimensional anatomically-accurate numerical model. There is good correlation between regions of signal loss in images and regions of high B_0 field gradients. The greatest B_0 distortion in the rat brain occurs in regions near the auditory canals. We anticipate that the results of these studies will be useful in understanding and eliminating imaging artifacts (6), as well as improving B_0 homogeneity in the rat brain.

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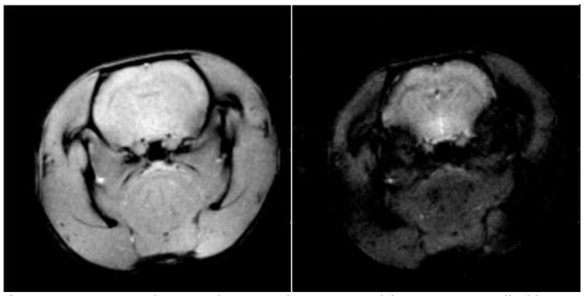

Figure 2: Experimental GRE images with TE=7ms (left) and 37ms (right) on coronal plane approximately 7 mm anterior to auditory canals.

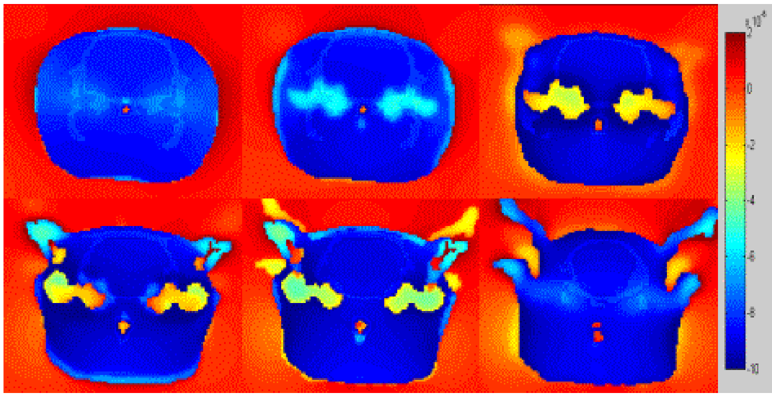

Figure 3: Calculated B_0 field magnitude on several axial slices through rat head model. Color scale on far right indicates B_0 strength from –10 to 2 ppm deviation from applied field. The regions of greatest gradients in calculated B_0 strength correspond to regions of greatest signal loss as TE increases in Figure 2.

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