Comparison of Magnetic Field Correlation in Brain at 1.5 and 3 Tesla

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Introduction An MRI method for estimating the magnetic field correlation (MFC) in brain has been recently proposed (1). The MFC is of interest as a quantitative metric of microscopic magnetic field inhomogeneities, such as those generated by non-heme iron concentrated in glial cells (2), and has potential applications to the assessment of disruptions in iron homeostasis associated with multiple sclerosis (3), Alzheimer's disease (4), and other iron-related neuropathologies. If the field inhomogeneities are assumed to scale linearly with the applied magnetic field, then the MFC will increase as the field squared. In order to further validate the MFC measurement method, we experimentally tested this predicted scaling behavior by scanning two human subjects at both 1.5T and 3T.

Theory Let $\delta B(t)$ be the magnitude of the local magnetic field difference, relative to the uniform background field, experienced by a water proton at a time t. The MFC is then defined as (1)

$$MFC(t-t_0) = \gamma^2 \left\langle \delta B(t) \cdot \delta B(t_0) \right\rangle \quad [1]$$

where γ is the proton gyromagnetic ratio and the angle brackets indicate an averaging over all the water molecules within a voxel. Typically, the field inhomogeneities represented by $\delta B(t)$ are due to spatial variations in magnetic susceptibility and thus are directly proportional to the applied field strength. From Eq. (1), it then follows that the MFC should scale as the square of the applied field. The proposed MFC estimation method (1) should, if valid, be able to demonstrate this scaling behavior.

Methods Two normal subjects (ages 44 and 43 years) were imaged on 1.5T (Avanto, Siemens Medical Solutions) and 3T MR systems (Tim Trio, Siemens Medical Solutions). In both cases, MFC imaging data were acquired using an asymmetric spin echo (ASE) sequence with refocusing pulse time shifts of 0, –4, –16 ms, a segmented echo planar imaging (EPI) readout, and the imaging parameters: repetition time = 5190 ms, echo time = 40 ms, acquisition matrix = 128×128, voxel size = 1.72×1.72×1.72 mm^3, EPI factor = 33, and averages = 8 and 4 for 1.5T and 3T, respectively. The echo time of 40 ms implies that the MFC values correspond to a time interval of 20 ms (1).

Data processing: The MFC data were processed using in-house MATLAB scripts (Mathworks, Natick, MA) with parametric maps being derived following the method of Ref. 1. Images and maps for 1.5T were co-registered to the conventional spin echo (i.e., zero refocusing pulse time shift ASE) images obtained at 3T. Four consecutive slices were chosen that included much of the basal ganglia, since this region is known to have relatively high MFC values (2). In order to reduce effects associated with noise, motion, and differences (for the two field levels) in brain orientation relative to the applied field direction, rectangular blocks of 256 adjacent voxels (64 voxels/slice) in the MFC maps were averaged to produce low resolution MFC maps with a voxel size of 13.8×13.8×6.9 mm^3. Rectangular regions of interest (ROI) within the subcortical brain were defined on the 3T conventional spin echo images and transferred to the low resolution MFC maps for both field levels (see Fig. 1); each ROI contained 28 low resolution voxels. The 1.5T and 3T low resolution MFC values were then correlated for all the voxels within the ROI.

Results Figure 1 shows representative spin echo images with sample ROI at both 1.5T and 3T, along with the corresponding MFC maps. Also shown are the low resolution MFC maps within the ROI used for the quantitative analysis. Figure 2 demonstrates the correlation between the 1.5T and 3T MFC values from the low resolution maps for both subjects. The linear correlation coefficient is $r = 0.94$, and the slope is 3.7 ± 0.1.

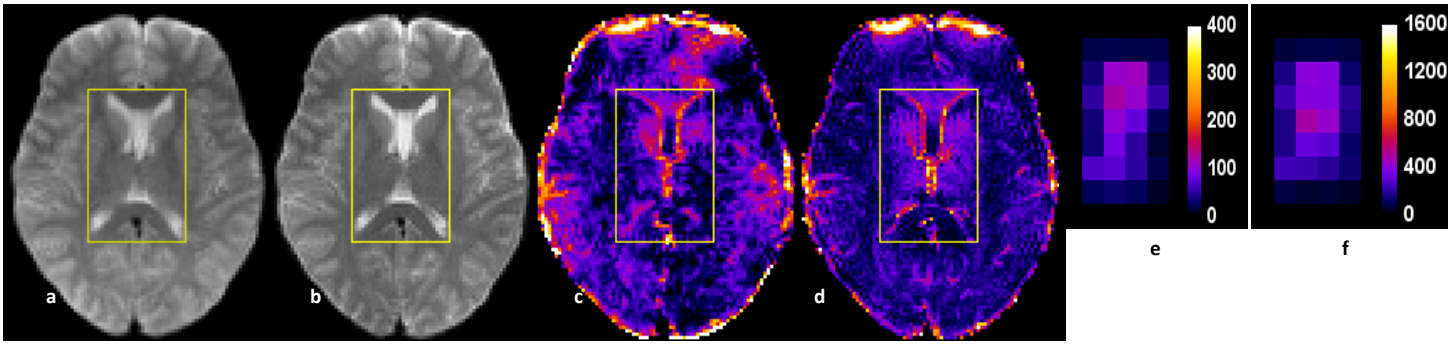

Figure 1: Spin echo images at 1.5T (a) and 3T (b) averaged over 4 slices and the corresponding MFC maps (c) and (d). The yellow boxes indicate the ROI used for the analysis. Low resolution MFC maps for 1.5T (e) and 3T (f) were calculated within the ROI to reduce minor differences related to noise, motion, and positioning. The scale bar for (e) also applies to (c), while the scale bar for (f) also applies to (d). Both scale bars are in units of (s^{-2}), and note that the range for 3T is four times that for 1.5T.

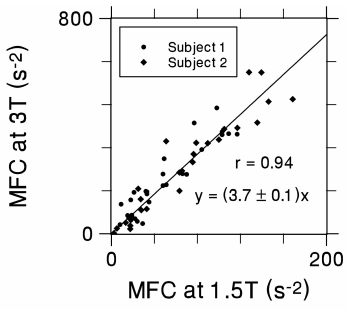

Figure 2: Correlation of 1.5T and 3T MFC values from low resolution maps for two subjects. The line is a least squares fit through the origin.

Discussion The precise magnetic field strengths for the 1.5T and 3T scanners are 1.4955T and 2.8952T, yielding a squared field ratio of 3.75, which is consistent with our experimental slope of 3.7 ± 0.1. This agreement provides a strong confirmation for the validity of the MFC measurement method for 1.5T and 3T within the basal ganglia. A test of field scaling for MFC imaging in brain for 3T and 7T has been previously reported by Versluis and coworkers (5), suggesting that MFC imaging may be applicable for the entire clinical field range from 1.5T to 7T .

References **1.** Jensen JH, et al. MRM 2006;55:1350. **2.** Jensen JH, et al. MRM 2009;61:481. **3.** Ge Y, et al. AJNR 2007; 28:1639. **4.** Ramani A, et al. ISMRM 2006;14:2655. **5.** Versluis MJ, et al. ISMRM 2009;17:4460.

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