Brain Iron in MR imaging: R_2^* and Phase Shift at Different Field Strengths

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Introduction: The shortening of T_2 relaxation time with increasing field strength associated with iron deposition was reported in [1]. This T_2 shortening has been attributed to iron-loaded ferritin and hemosiderin molecules that create microscopic field inhomogeneities and dephase water protons in the vicinity. If ferritin is responsible for the observed hypointensity, then it may exhibit magnetic saturation at higher field strengths [2]. Moreover, the iron-loaded ferritin also changes bulk susceptibility, resulting in a higher phase contrast in the iron-rich areas. This study measured the R_2^* and local frequency as a function of field strength in various brain regions, in order to determine whether contrast saturation occurs.

Methods and Materials: The study was conducted using three GE (General Electric) Signa whole-body MRI scanners with the field strengths of 1.5 T, 3 T and 7 T, respectively. On each scanner, a similar MRI protocol was followed and included the following scans: **1)** a fast 3-plane localizer; **2)** multiple T_2^*-weighted scan sessions using a single-echo GRE pulse sequence, at varying echo time; acquisition parameters were: FOV = 240 × 180 mm^2, matrix size = 256 × 192, 16 axial slices with slice thickness/spacing were 2.0/2.0 mm (1.5 T and 3 T) and 1.0/3.0 mm (7 T), receiver bandwidth = 31.25 kHz, TR = 1000 ms, flip angle = 60°; for 1.5 T twofold averaging was used to increase the SNR; **3)** 3D MP-RAGE based T_1-weighted imaging for anatomical ROI selection; acquisition parameters were: FOV = 240 × 180 mm^2, matrix size = 256 × 192, slice thickness was 2 mm (1.5 T and 7 T) or 4 mm (3 T), TI was 725 ms (1.5 T and 3 T) and 1200 ms (7 T), flip angle was 6° (1.5 T and 3 T) and 9° (7 T). The location of the slice coverage was carefully chosen so that it had the same center as the corresponding GRE images in the SI direction. Quantitative R_2^* maps (Fig. 1a) were made by acquiring T_2^*-weighted GRE images at 4 different echo times. A sixth order polynomial function was fitted to the phase map from the highest TE GRE images to determine the global background phase. Continuous phase maps in the areas of interest were then generated after subtraction of the phase background (Fig. 1b). The GRE images with echo time of 57.0/50.0/30.0 ms for 1.5 T/3 T/7 T were used to calculate the phase maps in order to obtain a higher phase contrast.

Each subject (n = 12) was scanned in all three scanners after giving informed consent. Four regions of interest (ROIs) were drawn on the 3 T MP-RAGE images (Fig. 1b): Putamen (PU), Caudate nucleus (CN), Thalamus (TH) and Corpus callosum (CC). The phase of CSF in the lateral ventricle (LV) was used as reference. Frequency shifts were directly calculated from the phase difference with respect to the reference in LV.

To compare the phase and R_2^* value changes at different field strengths, the 3 T MP-RAGE images were registered to the 1.5 T/7 T MP-RAGE images for each subject and then each set of the MP-RAGE images were registered to the corresponding GRE images (the GRE images with the shortest TE were used for registration). The ROIs were transferred to each R_2^* and phase map. The frequency and R_2^* values were averaged in each ROI for each individual.

Results and Discussion: Preliminary results for three subjects are shown. Fig. 2 shows the averaged R_2^* and frequency changes with field strength for the iron-rich regions (PU, CN, TH) and the iron-poor region (CC). Both the frequency shifts and R_2^* contrast increase with field strength. More importantly, the local MRI frequencies, which linearly relate to local susceptibility differences, show a significant departure from linearity. This suggests that the susceptibility effects in the investigated regions originate from a contrast mechanism that saturates at higher field strengths, as might be expected from ferritin molecules with a high loading factor.

References: [1] JF Schenck, *J Neurological Sci.* 134 (Suppl.): 10-18, 1995; [2] A Bizzi et al, *Radiology* 177: 59-65, 1990

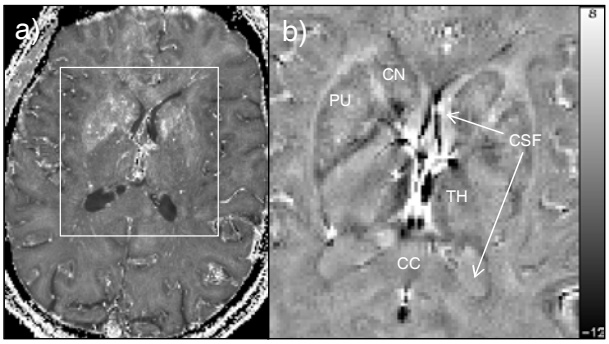

Fig. 1: a) *A 7 T R_2* map.* ***b)*** *Frequency map of the zoom-in portion (box in a). Different ROIs are indicated: Putamen (PU), Caudate nucleus (CN), Thalamus (TH), Corpus callosum (CC) and Cerebrospinal Fluid (CSF).*

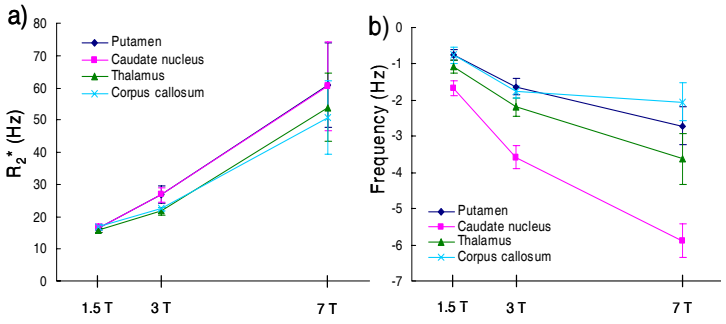

Fig. 2: a) *Averaged R_2* values in different ROIs at 1.5 T, 3 T and 7 T. The Error bars indicate the standard error.* ***b)*** *Averaged frequency values in different ROIs relative to CSF.*