Simultaneous T_1 and T_2 quantitation of the Human Brain at 7 Tesla by MR Fingerprinting

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Target audience: Those interested in developing novel methods in quantitative imaging in humans at ultra-high field.

Purpose: The purpose of this work is to achieve rapid quantification of multiple relaxation parameters in the human brain at ultra-high field using MR Fingerprinting (MRF)[1]. The intrinsically high SNR property at ultra-high field provides potential for better visualization of fine scale structures. However, inhomogeneities in the main field (B_0), the transmit field (B_1^+), and increased SAR present a challenge to quantify the relaxation parameters at 7 Telsa and above. The recently proposed MRF method has been shown to be extremely efficient in the quantitation of relaxation parameters, and may offer some advantages to avoid limitations associated with quantitative methods at 7T. Here, we demonstrate the quantification of T_1 and T_2 in human brain at 7 Tesla with MRF.

Methods: The original MRF method was based on an Inversion Recovery balanced Steady-State Free Precession (IR-bSSFP) sequence; however, this sequence suffers from banding artifacts due to the B_0 inhomogeneties at ultra-high field. In this study we used an MRF method based on the Fast-Imaging with Steady-state free Precession (FISP) type sequence[2] to avoid these banding artifacts An unbalanced gradient within each repetition time was used to achieve 8π dephasing across each voxel. To generate unique signal shapes for different tissue types in MRF, the flip angles were sinusoidally varied from 5°~75°, and the repetition times were smoothly varied from 11.6 to 14.6 ms using a Perlin noise pattern. A variable-density spiral trajectory using the minimum-time gradient design[3] was used to acquire the data. The spiral trajectory requires 24 interleaves to fully sample the inner region, and 48 interleaves to fully sample the outer 256 x 256 region of k-space. The in-plane spatial resolution is 1.2 mm^2 with the slice thickness of 5mm. 2000 time points with one spiral interleaf per time point were acquired for the MRF scan, resulting in a total scan time of 30 seconds. To address the transmit field (B_1^+) inhomogeneities at 7T, an additional B_1^+ measurement was acquired by the actual flip angle method[4] with the same spiral trajectory. The spiral AFI scan time was 25 seconds. All acquired data were reconstructed using NUFFT[5].

A dictionary containing the signal evolutions with a range of T_1 (20~5000 ms), T_2 (10~500 ms), and B1 (10%~120%) was simulated by the extended phase graph (EPG) algorithm[6]. All studies were performed on a Siemens 7T (Siemens AG Healthcare, Erlangen, Germany) with a custom 32 channel head receiver array. A template-matching algorithm was used to extract T_1 and T_2 values by matching a dictionary entry to the acquired signal evolution. A voxel specific dictionary was used to account for flip angle variation due to B_1^+ inhomogeneity as estimated with the AFI scan.

Results: Figure 1 shows T_1, T_2 and proton density maps generated for an asymptomatic volunteer, and a B_1^+ map from the AFI method. The mean values of T_1 and T_2 from white matter and grey matter are in good agreement with the literature results[7]. Table 1 lists the T_1 and T_2 values from this study and the literature.

Table 1. T_1 and T_2 relaxation times and their standard deviations of MRF-FISP at 7 T, and the corresponding values reported in the literature[7,8]

Tissue	T_1 (*ms*)	T_1 (*ms*)	T_2 (*ms*)	T_2 (*ms*)
	MRF-FISP	Literature (7)	MRF-FISP	Literature (8)
White matter	1140~1240	1285	45~60	48
Gray matter	1780~2050	1954	56~76	63

Discussion: We showed initial results in quantification of T_1, T_2 and proton density with the MRF at 7 T. In this initial study, we used an extra B_1 measurement to address the inhomogeneous B_1 at ultra-high field. With additional B_1 measurement time, MRF is able to quantify T_1 and T_2 values within one minute per slice.

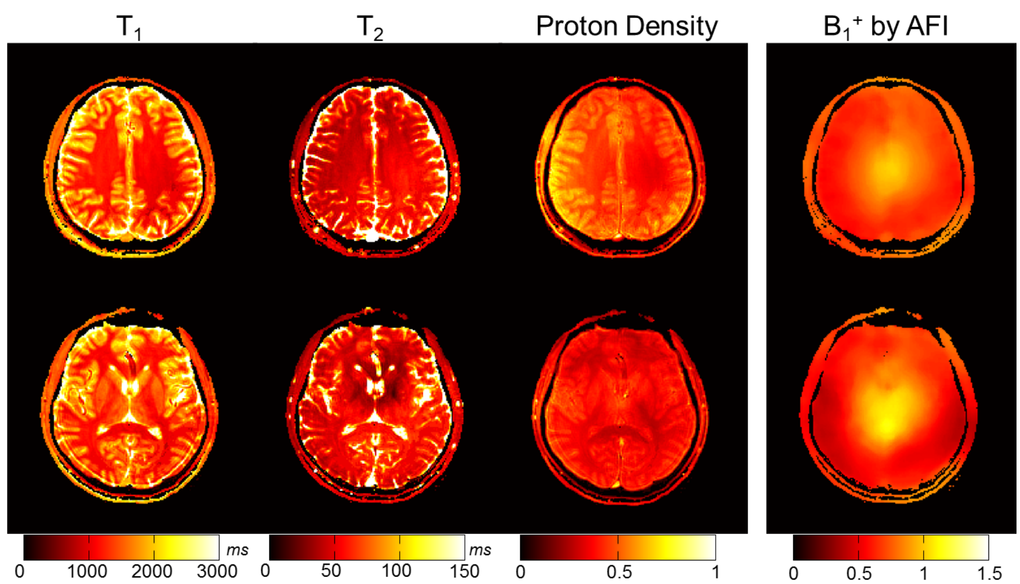

Figure 1. T_1, T_2 and proton density maps of a human brain by MRF-FISP, and the transmit B1 map by the AFI method at 7 Tesla.

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