Abstract #06155 ISMRM ABSTRACT

[USGOV] Clinical Acquisition of Joint T1-T2 Contrast-Encoded MRI at 0.064T

Primary: Physics & Engineering - Low-Field MRI 〉 **Secondary:** Acquisition & Reconstruction - Pulse Sequence Design: Neuro 〉 **Presentation:** Oral, Digital Poster, PowerPitch Oral 〉 **Keywords:** CLINICAL APPLICATION SEQUENCE DEVELOPMENT ULTRA LOW-FIELD MRI MULTI-DIMENSIONAL ENCODING

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Impact

Achieving joint T_1–T_2 encoding *in vivo* at 64 mT establishes a foundation for future multi-dimensional MRI studies on portable low-field scanners. This capability enables new scientific questions about tissue composition and supports wider deployment of quantitative imaging in resource-limited environments.

Synopsis

Motivation: Portable ultra-low-field MRI could expand access to quantitative neuroimaging, but multi-dimensional contrast encoding has not yet been demonstrated *in vivo* at 64 mT.

Goals: To translate two-dimensional T_1–T_2 spectral MRI from phantom validation to a clinically feasible whole-brain protocol on a 64 mT MRI scanner.

Approach: We developed an IR-FSE sequence combining inversion-recovery and multi-echo preparation to jointly encode T_1 and T_2 contrasts, and acquired whole-brain multi-dimensional data with a wide range of inversion and echo times.

Results: The method produced images with large dynamic range and enabled robust voxel-wise T_1–T_2 spectral characterization in healthy volunteers.

Introduction

There is increasing momentum behind ultra-low-field (ULF) MRI for expanding neuroimaging access, including in low- and middle-income countries where portable systems may support neonatal care and large-scale neurodevelopmental studies [1,2]. Although multi-dimensional MRI approaches capable of jointly encoding relaxation or diffusion parameters are well established at conventional field strengths, they have not yet been translated to ULF scanners. These methods use systematically varied contrast weightings to recover voxel-wise correlation spectra that reflect underlying biophysical properties and are widely applied in relaxometry–diffusometry studies [3,4]. Prior work demonstrated that two-dimensional T_1–T_2 spectral imaging is feasible at 0.064 T using a controlled phantom environment [5]. Building on this foundation, the current study adapts and optimizes the methodology for in-vivo human brain imaging, aiming to develop a clinically practical protocol on a Hyperfine 64 mT scanner. This represents an important step toward quantitative multi-dimensional ULF MRI in real-world clinical settings.

Methods

Measurements were performed on a 0.064 T Hyperfine Swoop® MRI scanner (hardware 1.6, software rc9.0.0_Beta1, Guilford CT, USA) using an 8-channel receive and 1-channel transmit RF coil. An inversion-recovery 3D fast spin echo (IR-FSE) sequence was developed to enable two-dimensional T_1–T_2 spectral encoding on this ULF system (Fig. 1). Images were acquired at 2.5 mm² in-plane resolution, 6 mm slice thickness, with a 180×220×156 mm³ field of view and TE/TR=4.92/1400 ms. Total scan time was 100 minutes.

To maximize the number of sampled echo times while maintaining a feasible acquisition duration, we acquired four phase-encoding lines per excitation. Each scan used 80 refocusing pulses, yielding 20 echo images spanning at 5.1:20.5:394.2 ms, along with nine inversion times (18, 31, 53, 92, 157, 271, 465, 800, and 1200 ms) and a reference dataset without an inversion pulse.

A 28-year-old healthy volunteer was scanned under an IRB-approved clinical protocol.

Analysis

The relaxation-weighted images were used to estimate the joint T_1–T_2 distribution using a modified marginal-distributions constrained optimization (MADCO) approach[3]. For each voxel, 1D marginal T_1 and T_2 distributions were first estimated via L2-regularized least squares and used to both restrict the admissible T_1–T_2 search space and provide constraints in the subsequent joint estimation. The T_1 and T_2 axes were discretized logarithmically from 1–5500 ms in 51 steps, and the optimization was implemented in CVXPY. Spectral reconstructions were also performed without marginal constraints for comparison[4].

Spectral features were derived using several metrics. First, voxel-wise mean and standard deviation maps of T_1 and T_2 were computed. Second, the 2D spectrum was integrated within predefined bins: myelin water (T_1=0–200, T_2=0–50 ms), tissue water (T_1=200–500, T_2=60–120 ms), and CSF (T_1=500–5000, T_2=150–2000 ms).

Results

Figure 2 shows five representative slices across a subset of the acquired T_1- and T_2-weighted images, illustrating the wide range of signal attenuation achieved by varying both inversion time and echo time. The combined contrast modulation highlights tissue-dependent relaxation behavior and demonstrates the ability of the IR-FSE acquisition to jointly encode T_1 and T_2 information across the brain volume.

Figure 3 presents the spectral analysis performed using the MADCO approach. For each voxel, the two-dimensional T_1–T_2 spectrum was estimated, from which maps of mean T_2, standard deviation of T_2, and mean T_1 were derived. Tissue characterization was performed by optimizing voxel-wise thresholds to identify distinct spectral components, yielding maps of myelin-water fraction, tissue water fraction, and CSF fraction.

Figure 4 shows the analysis performed using conventional L2-regularized multidimensional spectral reconstruction without marginal distribution constraints. The spectral display in Fig. 4a reveals spatial maps of spectral amplitudes in the T_1–T_2 space. Tissue-fraction maps were computed from the spatial-spectral maps (Fig. 4b). For reference, Fig. 4c shows maps of voxel-averaged proton density, T_1, and T_2 were generated obtained with conventional MRI relaxometry.

Discussion

This work demonstrates the feasibility of jointly encoding T_1 and T_2 contrast at 64 mT by integrating inversion-recovery and multi-echo preparations within a single IR-FSE acquisition. The resulting imaging data provided a relatively high-SNR, and whole-brain coverage with a large dynamic range of signal attenuations, enabling robust estimation of voxel-wise T_1–T_2 spectral properties. By sampling a broad combination of inversion and echo times, the protocol captured a wide range of joint T_1–T_2 encodings, producing diverse contrasts that enhanced tissue separability in both model-based and spectral analyses. These findings establish a practical pathway for quantitative, multi-dimensional MRI on portable ULF systems to support further clinical translation.

Conclusions

This study demonstrates that joint T_1–T_2 spectral encoding is feasible in vivo at 64 mT using an optimized IR-FSE acquisition. The resulting whole-brain datasets enable robust quantitative mapping and support the clinical translation of multi-dimensional MRI to portable ULF systems.

Acknowledgements

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Figures and Tables

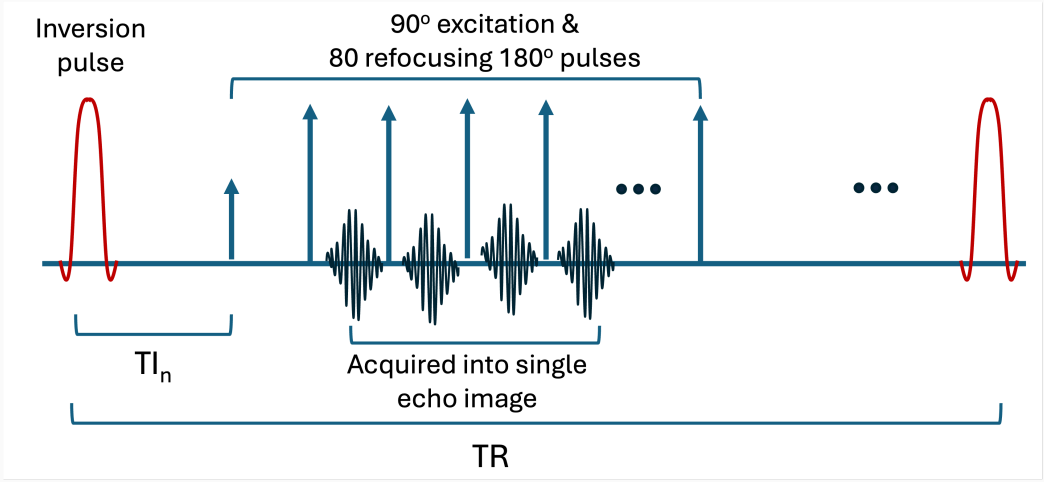

Figure 1: Fig. 1*: Pulse-sequence diagram of Inversion-Recovery (IR) 3D fast spin echo (FSE). The sequence consists of an adiabatic inversion pulse, a multi-echo output train with 4 phase-encoded lines per image, and multiple repetitions with varying inversion times (TI).*

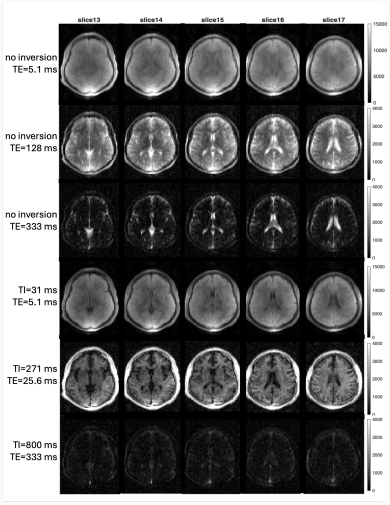

Figure 2: Fig. 2: *Reconstructed images from five slices at six different combinations of T_1 and T_2 weightings.*

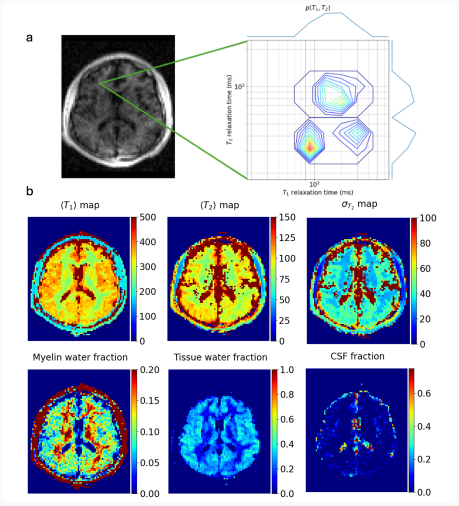

Figure 3: Fig. 3: *(a) Two-dimensional T_1–T_2 spectral distribution from a single voxel. (b) Fitted quantitative maps of mean T_1, mean T_2, and T_2 standard deviation (upper row), and the derived myelin-water, tissue-water, and CSF fractions (lower row).*

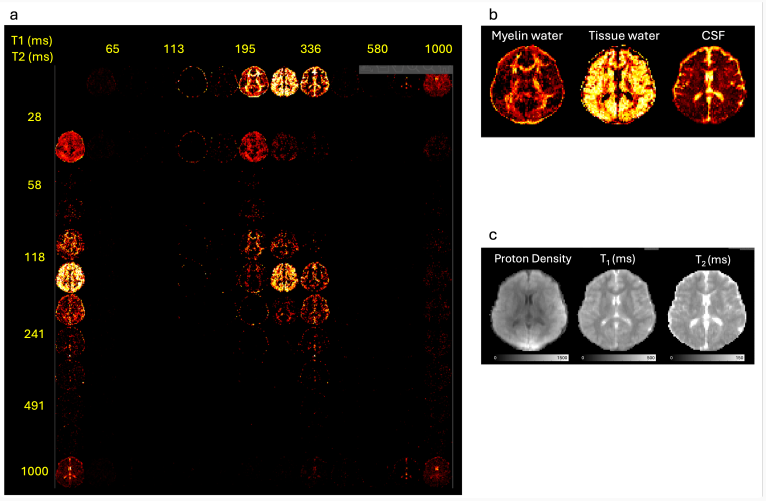

Figure 4: Fig. 4. *(a) Two-dimensional T_1–T_2 spectral representation of a single slice. (b) Estimated tissue-fraction maps for myelin water, tissue water, and CSF.(c) Quantitative maps of voxel-averaged T_1, T_2, and proton density.*