High Resolution Multispectral qMRI Protocol: PD, T1, T2, T2*, ADC, MT

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Purpose: The purpose of this study was to develop a high-resolution, multi-spectral, quantitative magnetic resonance imaging (qMRI) pulse sequence protocol to interrogate T1, T2, T2*, proton density (PD), diffusion coefficient, and magnetization transfer parameters at ultra-high field (11.7T) MRI.

Methods: Imaging experiments were performed using 11.7T MRI. All pulse sequences were implemented in the axial plane, with the following common geometry parameters: voxel dimensions=100x100x600μm^3 and matrix=256x256.

We implemented a dual sequence version of the mixed-TSE sequence, termed here as tandem-mixed-TSE with the following parameters: pulse sequence 1, dual-echo RARE: TE_1=14ms, TE_2=27ms, TR=4000; pulse sequence 2, dual-echo RARE with inversion recovery pulse: TE_1=14ms, TE_2=27ms, TI=400ms, TR=4400ms (Figure 1) (1). Images acquired with these two sequences were used to calculate parametric PD, T_1, and T_2 maps. A tri-echo gradient echo (FLASH) with the following parameters was implemented: TE1=4.5ms, TE2=6.8ms, TE3=9.0ms, TR=140ms, flip angle=30° (Figure 2). Directly acquired images were used to construct parametric T2* maps (Figure 2). For diffusion weighted MRI (DWI), a multi-slice spin echo image pulsed field gradient (PFG) acquisition (TE=10ms, TR=2000ms) was utilized with b-values of 21, 301, and 601 s/mm2 for constructing parametric ADC maps (Figure 3). For the quantitative magnetization transfer (qMT) experiments, we used a single 15ms Gaussian pulse with 13 frequency offsets ranging from ranging from 435Hz to 50kHz (logarithmic spacing). A single magnetization transfer pulse power was used (16uT). A two-dimensional spoiled gradient echo sequence (FLASH) was used with the magnetization transfer pre-pulse for image acquisition with the following parameters: TE= 4ms, TR=260ms, flip angle=30^o (Figure 4). An additional reference dataset with the identical parameters was also acquired without a magnetization transfer pulse.

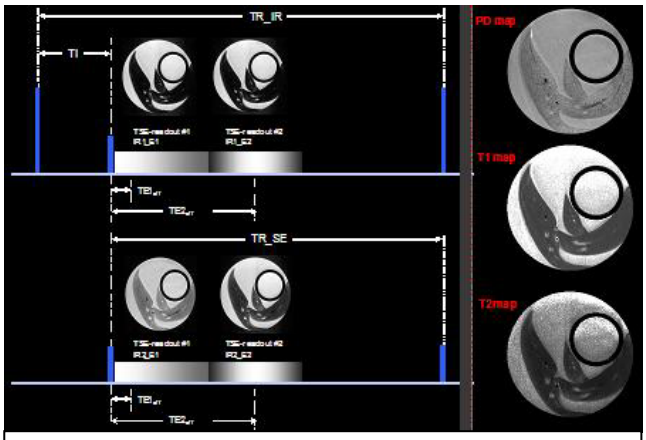

Figure 1. Mixed-TSE pulse sequence used to generate parametric PD, T1, and T2 maps of murine liver (shown to right).

This multi-spectral qMRI pulse sequence was applied to a qMRI phantom containing water, agarose gels, sucrose solutions, and olive oil. Also, the protocol was applied to *ex vivo* liver imaging of a murine model of steatohepatitis as well as *ex vivo* murine brain imaging; all tissue imaging was carried out at 23.5°C using an internal reference vial containing phosphate buffered saline (PBS) and olive oil. T1 relaxation time determination using the tandem-mixed-TSE sequence was validated using an accepted, well established qMRI sequence using multiple inversion times.

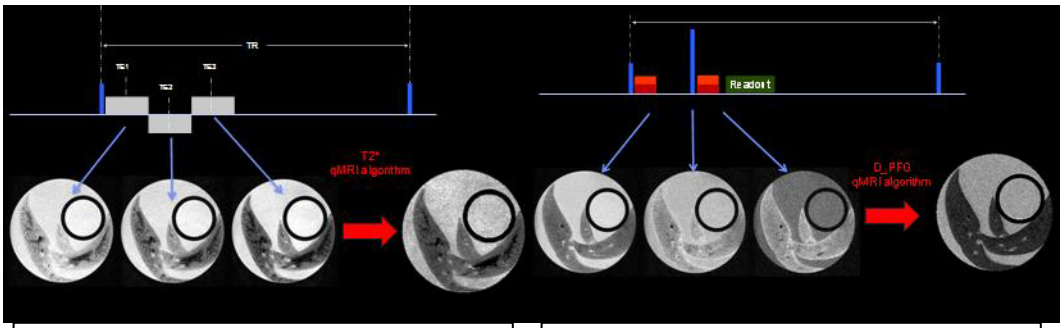

Figure 2. Tri-echo gradient echo used to generate T2* maps of murine liver (shown to right).

Figure 3. SE PFG pulse sequence used to generate ADC maps of murine liver (shown to right).

Results: Excellent directly-acquired and qMRI map image quality was obtained for all of the MRI parameters at 11.7T (Figures 1-4). Excellent agreement between the tandem-mixed-TSE and the multi-IR sequence was found for the phantom materials/internal references within the tissue samples: $T1_{olive\ oil}$=430ms, $T1_{agarose}$=1767ms, $T1_{PBS}$=2054ms, $T1_{water}$=2054ms. The diffusion coefficient for the water was determined to be 2.4cm^2/sec, in excellent agreement with known values at 23.5°C (2). Magnetization transfer experiments generated expected results with varying agarose gel concentration in the phantom imaging experiments.

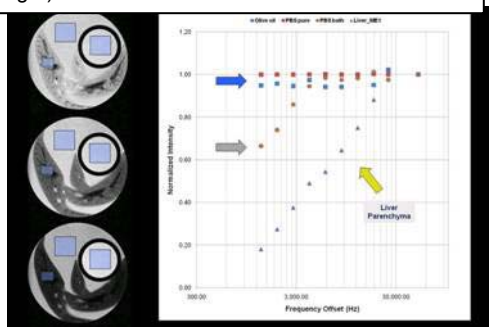

Figure 4. Directly acquired qMT images of murine liver (representative 3 shown to left) used to generate frequency offset versus signal intensity curves (shown to right).

Conclusion: We have developed a comprehensive, multi-spectral qMRI protocol affording high-resolution imaging at 11.7T MRI. We envision myriad applications for a complete, multi-spectral qMRI protocol such as we have successfully implemented.

References

1. Farraher S, Jara H, Chang K, Hou A, Soto J. Liver and spleen volumetry using Quantitative MR Imaging (Q-MRI) and dual-space clustering segmentation. Radiology 2005; 237(1):322–328.
2. Tofts PS, Lloyd D, Clark CA, Barker GJ, Parker GJ, McConville P, Baldock C, Pope JM. Test liquids for quantitative MRI measurements of self-diffusion coefficient in vivo. Magn Reson Med. 2000; 43(3):368-374.