3D Ultrashort Echo Time (UTE) Imaging in the Brain at 7T

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Introduction: Ultrashort echo time (UTE) imaging offers advantages in being able to directly image tissues with T2 values less than a few milliseconds, such as tendons and cortical bone [1]. In the brain, short-T2 components are present in white matter [2] - believed to be associated with myelin – as well as in connective tissues and calcifications, and these are known to be altered in neurodegenerative diseases and other neurological pathologies.

Methods: Two primary challenges faced by UTE MRI are low signal intensity for short-T2 components and short-T2 component contrast from surrounding long-T2 components that generally have higher signal intensities. We used an ultra high-field GE 7T MR scanner where the increased field strength provides improved overall SNR as compared to 3T and 1.5T used in prior UTE studies. Images were acquired using quadrature transmit and 8-channel receive head coils. The 3D radial readouts [3] had anisotropic 20x22x22 cm FOV and 1x1x3 mm resolution [4], acquired in 5 min 18 s. Other parameters were 50 μs 10° hard pulse excitation, TE (as defined from end of RF pulse to start of readout gradient) = 64 μs, 1 ms readout duration, TR = 5 ms, 62,933 half-projections, and a gridding reconstruction. Contrast was generated by acquiring a second image with either TE = 1ms or an off-resonant fat suppression pulse applied at -1 kHz. For improved efficiency, each suppression pulse was followed by 6 excitations/readouts.

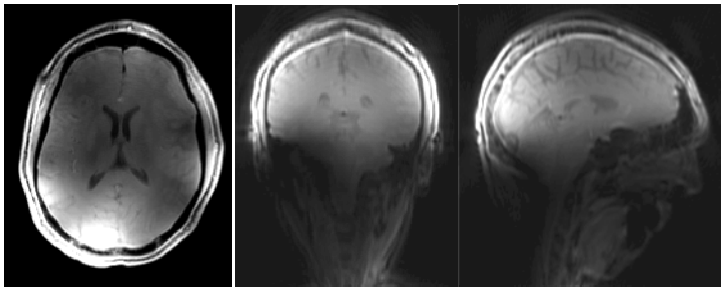

Figure 1: The 3D UTE acquisition covered the entire brain in just over 5 mins at 7T and the data can be viewed in any orientation.

Results: Full brain coverage was acquired (Fig. 1) and no slice-select gradients were required, which can induce eddy current distortions. The TE=64μs images had high SNR throughout the anatomy but little contrast between tissues (Fig. 2, left). They also demonstrated signal from bone in the skull. Subtraction of a TE=1ms image (Fig. 2, right) highlights several structures with short-T2 components, such as the falx cerebri and optic nerve. Application of fat suppression pulses resulted in attenuation of the fat signal (Fig. 3, right) and B1 inhomogeneity compromised the suppression. This also saturated short-T2 components, which have a broad spectral width, as well as indirect saturation of long-T2 components due to magnetization transfer, creating gray/white matter contrast. Therefore, subtracting images with and without suppression pulses highlighted short-T2 components, nearly identically to the UTE off-resonance saturation contrast method [5]. This increased white matter contrast presumably is due to its myelin content. There were some variations in contrast across the brain primarily due to B1 inhomogeneity of the suppression pulses.

Conclusions: We have developed a rapid, efficient 3D UTE imaging sequence for whole-brain coverage at 7T MRI in 5 mins 18 s. Our initial results show good SNR as well as several mechanisms for obtaining short-T2 tissue contrast of connective tissues and white matter.

References: [1] Gatehouse et al, Clin Radiol 2003; 58: 1-19. [2] Waldman et al, Neurorad 2003; 45: 887-892. [3] Rahmer et al, MRM 2006 55(5): 1075-1082. [4] Larson et al, IEEE Trans Med Imag 2008; 27(1): 47-57. [5] Du et al. MRM 2009; 62(2): 527-531.

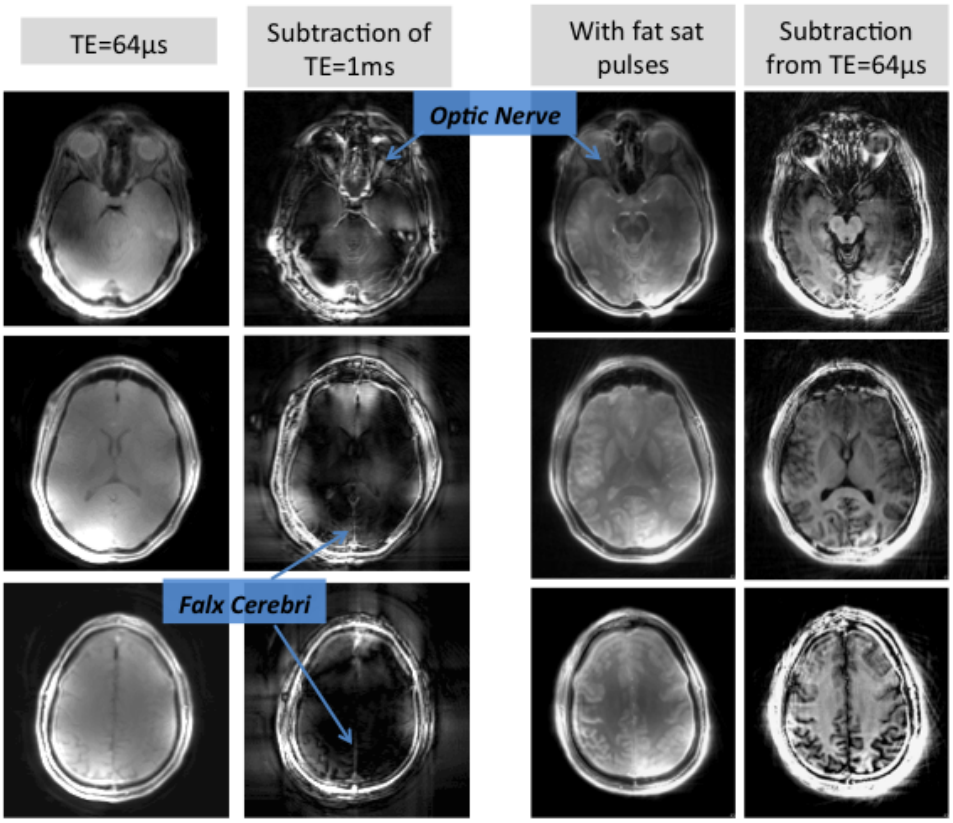

Figure 2: Subtracting the later TE images highlights several structures with short-T2 components, including the optic nerve and falx cerebri.

Figure 3: The fat sat pulses not only attenuate the fat signal but also saturate short-T2 components in the brain. The subtraction image highlights short-T2 components in white matter across the cerebrum as well as in the cerebellum and brain stem.

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