A high resolution high SNR 3D T2prep spiral protocol for robust whole brain myelin water quantification at 3 Tesla

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INTRODUCTION Multi-component T2 relaxometry (1-3) has the potential to quantify myelination in diseased cerebral white matter (WM) for multiple sclerosis patient monitoring and treatment evaluation. In the conventional approach, T2 data is acquired using a time-consuming 2D multi-echo spin echo (MESE) sequence (26 min per slice) (4), preventing whole brain coverage. Recently, an SNR efficient 3D T2prep spiral gradient echo (3DSPIRAL) sequence has been developed to shorten the acquisition time to less than a minute per slice while providing similar myelin water fraction (MWF) measurements compared to MESE at 1.5T (5). As multi-exponential T2 data fitting is highly sensitive to noise (6), higher field strengths would greatly benefit the accuracy and reproducibility of MWF mapping due to SNR advantage. The objective of this study is to develop a high resolution and high SNR 3DSPIRAL protocol for whole brain MWF mapping at 3T and to evaluate its performance in healthy volunteers by comparing with the conventional 1.5T acquisition.

METHODS Eight healthy volunteers (7 men, 1 woman, 30 ± 5 yo) were imaged with an optimized 3D SPIRAL protocol (FOV=26 cm; 26 T2prep times=3, 6, 10-160 ms (10 ms step), 180-320 ms (20 ms step); matrix=160x160 interpolated to 256x256; slice=5 mm; number of slices=28; spiral TR/TE=5.0/0.7 ms; number of spiral leaves=48; 8-channel receive coil). Two composite $90_x 180_y 90_x$ refocusing pulses were used in T2prep to improve T2 weighting accuracy against increased B_0 and B_1 imperfections at 3T (7). The study consisted of two scans performed at 1.5T with TR = 2.5 sec and 1.5 sec (corresponding to 26 and 16 min scan time) to investigate the effect of TR on MWF quantification with 3DSPIRAL, followed by a scan at 3T with TR=2.5 sec. T2 distributions were obtained using a regularized non-negative least squares fitting (4) for matching ROIs placed within six WM and GM regions. Each T2 distribution contains 120 logarithmically spaced T2 values within the range of 5 ms to 2000 ms. Voxel-wise MWF was calculated by dividing the sum of T2 components under 50 ms and 40 ms for 1.5T and 3T data, respectively, by the sum of all T2 components. The voxel-wise MWF values were then averaged over the ROI to provide a single MWF measurement for each ROI and subject. SNR was measured in the splenium of corpus callosum (CC) from the image with the shortest T2prep time (3 ms) and noise correction for a multi-receiver coil was applied. To compare error of MWF measurements, the coefficient of variance (COV) was also calculated for each ROI within each subject.

RESULTS All scans were completed successfully. Table 1 summarizes the MWF values obtained from three WM and three GM regions in 8 subjects. The 3DSPIRAL protocol provided consistent MWF values at both 1.5T and 3T. SNR was reduced from 155 ± 14 for TR=2.5 sec to 121 ± 9 for TR=1.5 sec at 1.5T. Acquiring data at 3T approximately doubled the SNR to 277 ± 43, leading to reduced COV for MWF measurements in all brain regions (Fig.1) and better MWF maps (Fig.2).

DISCUSSION Several studies (4,8) have shown a large MWF increase in major brain structures at 3T compared to 1.5T and attributed this effect to increased B_1 transmit field inhomogeneity and susceptibility induced local dephasing at higher field strengths. In this study, similar MWF values were observed at both 1.5T and 3T. Unlike prior studies in which a 2D sequence with relatively low SNR (about 80) was used at 1.5T, the 3DSPIRAL sequence employed in this study provided fairly high SNR at both field strengths. Furthermore, the use of a T2prep module for T2 weighting in 3DSPIRAL enables the acquisition of relaxometry data at echo times as short as 3 ms as compared to 10 ms with MESE. It is conceivable that these improvements in data quality may lead to more robust MWF estimates across field strengths. Our results also indicate that scan time may be shortened by reducing TR at the cost of increased MWF variability due to SNR loss. In conclusion, 3DSPIRAL acquisition at 3T is a promising approach to obtain whole brain T2 relaxometry data for robust in vivo myelin quantification.

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Table 1. MWF comparison (n=8). Data are presented as mean ± SD. P values are shown for comparison with MWF obtained with 1.5T TR=2.5s

Structure	1.5T TR=2.5s	1.5T TR=1.5s	P	3T TR=2.5s	P
Genu CC	9.3 ± 2.5	9.1 ± 1.7	0.80	8.8 ± 1.3	0.40
Splenium CC	9.8 ± 1.6	10.6 ± 1.1	0.23	10.1 ± 1.1	0.80
Internal capsule	10.6 ± 1.1	10.3 ± 0.9	0.70	11.4 ± 0.9	0.78
Caudate	2.9 ± 1.3	2.7 ± 0.7	0.78	3.4 ± 1.3	0.24
Putamen	2.5 ± 1.3	2.3 ± 1.1	0.90	2.8 ± 0.9	0.66
Thalamus	3.8 ± 1.3	3.8 ± 0.8	0.86	4.5 ± 0.6	0.29
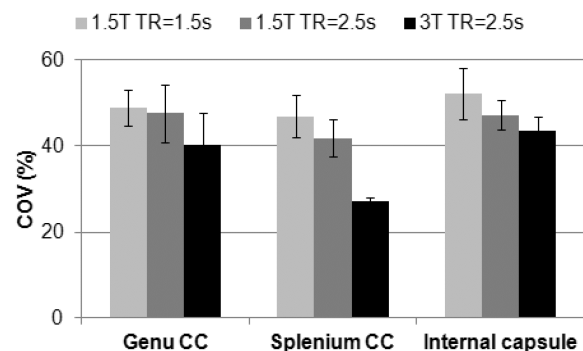
Fig.1. Comparison of coefficient of variance (COV) of MWF obtained with 3DSPIRAL at different TR and B_0.
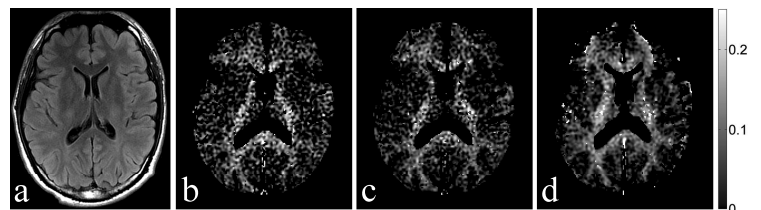
Fig.2. Anatomical T2 FLAIR image (a) and MWF maps from one subject obtained with TR=1.5s (b) and 3s (c) at 1.5T and TR=2.5s at 3T (d).