Reduced specific absorption rate (SAR) and scan time using variable density Magnetization Transfer (vdMT) for 7T

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INTRODUCTION As the number of ultra-high field (UHF; ≥ 7T) MRI installations grows, the need to establish high resolution MRI imaging protocols for clinical use using UHF MRI has become important. UHF MRI such as 7T has advantages in signal-to noise ratio (SNR) and image contrast and resolution (1). For this reason, UHF MRI could provide further insights into diseases not previously appreciated at lower field strengths. Magnetic transfer ratio (MTR), provides quantitative information about tissue structure and pathological changes. Thus it has been proposed as a potential biomarker for myelin concentration in the brain (2, 3). Due to much higher specific absorption rate (SAR) of tissue and much longer acquisition time at UHF, however, *in vivo* studies using MT at UHF MRI has not been feasible in an acceptable scan time. In this work, we described a novel MT acquisition scheme within a clinically reasonable time (<6 min). Our proposed new approach uses a combination of higher density of MT pulses applied to the center k-space lines and sparsely applied MT pulses in the outer k-space lines. With new proposed MT acquisition scheme, the scan time is reduced considerably (4.58 min) while maintaining similar MTR contrast comparable to MT pulse applied in all k-space lines (conventional method; 12.16 min).

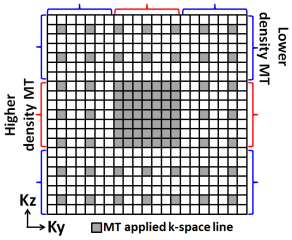

Figure 1. Proposed vdMT k-space acquisition diagram. Gray dots indicate MT pulses applied k-space line.

METHODS In-vivo (IRB-approved) data were acquired on a 7T MRI scanner (MAGNETOM 7T, Siemens) using a 32-channel phased array head coil (Nova Medical). ***Variable density MT (vdMT) sequence:*** MT pulses are applied every repetition time (TR) in a center of k-space, and sparsely applied in a peripheral k-space region. Combinations of the higher MT density area in the center of the k-space (referred as 'H' index here), density level of MT applied k-space line in k-space peripheral region (referred as 'R' index here) and TR were tested to confirm optimal values for MTR and to compare original MT (MT_{full}) image (i.e. MT_{H40R3} represent MT pulses are applied every TR with 40% of k-space based on the center and MT pulses are applied every third TR in peripheral k-space). These results were incorporated into the design of vdMT sequence (Fig. 1). MT RF pulse (flip angle: 540, duration: 7.68 ms, offset frequency 2 kHz) was used with 3D GRE readout. ***MRI data:*** Five MT data acquisitions were condected as follows: ***Scan 1)*** MT pulse applied in all k-space lines (MT_{full}): resolution = 1.0 mm^3 iso, TR = 108 ms, TE = 3.2 ms, 88 slices, GRAPPA factor = 3, partial Fourier = 6/8 in k_y and scan time = 12.16 min. ***Scan 2)*** MT_{H40R3}: the same parameters as in Scan 1 except TR = 47 ms, and scan time = 5.21 min. ***Scan 3)*** MT_{H40R5}: the same parameters as in Scan 1 except TR = 36 ms, and scan time = 4.06 min. ***Scan 4)*** MT_{H40R7}: the same parameters as in Scan 1 except TR = 31 ms, and scan time = 3.32 min. ***Scan 5)*** High resolution MT (MT_{H40R3}): the same parameters as in Scan 2 except resolution = 0.6 mm^3 iso, TR = 43 ms, and scan time = 6.04 min. Matched non-MT data were acquired in all cases for MTR calculation. All data were acquired in the same session. ***Data analysis:*** After generating MTR maps from each parameter, B_1 field inhomogeneity induced error was corrected using acquired B_1 map (4). To test similarity between original (MTR_{full}, Fig. 2A) and proposed method (MTR_{H40R3}, Fig. 2B) a voxel-wise correlation was calculated in voxels within a brain tissue mask. To measure the similarity, ROI analysis was performed (10 ROIs were placed) through the brain.

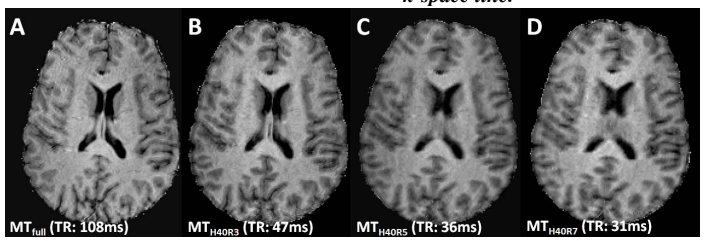

Figure 2. MTR for healthy subject. (A) MTR_{full} (TA: 12.16min) (B) MTR_{H40R3} (TA: 5.21min), (C) MTR_{H40R5} (TA: 4.06min) and (D) MTR_{H40R7} (TA: 3.32min).

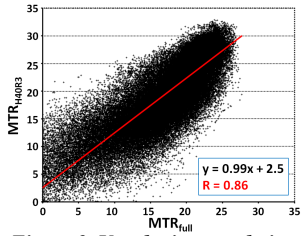

Figure 3. Voxel-wise correlation between MTR_{H40R3} and MTR_{full}

RESULTS Figure 2 shows MTR maps from conventional MT and vdMT with three different parameters. All results reveal good contrast between gray and white matter. Compared to conventional MTR (Fig. 2A), however, vdMTR results (Figs. 2B-D) show degraded image quality and slightly higher (8.8 ± 1.9%) value over 10 different ROIs. As the MT applied rate ('R' index) in the outer region of the k-space area is increased the image sharpness also increased (Fig. 2B). When the voxel-wise correlation was performed (Fig. 3), the correlation coefficient (cc) was 0.86 and the slope of trend line was 0.99, suggesting a high similarity between the two MTR maps. Figure 4 shows axial slice high resolution (0.6 mm^3 isotropic voxel) MTR map from the proposed vdMT (MT_{H40R3}, TR = 43 ms) parameter. In the expanded MTR map, shown in Fig. 4B, small structure such as vein is clearly delineating. This map also shows a similar MTR distribution to a MTR map using original MT (Fig. 2A, MT_{full}) method. When the ROI analysis performed, mean difference over 10 different ROIs between high resolution combined vdMT (Fig. 4, 0.6 mm^3) and the conventional MT (Fig. 2A) was 2.9 (± 4.4%), indicating good agreement between two methods.

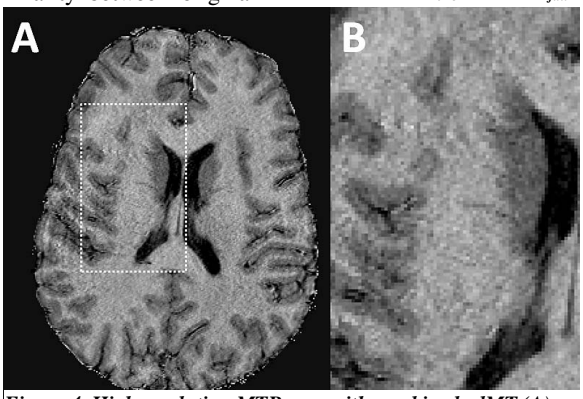

Figure 4. High resolution MTR map with combined vdMT (A) and magnified image (B). 0.6 mm^3 isotropic voxel; FOV = 192 × 192 × 53 mm^3; TR = 43ms; 6.04 min scan time.

DISCUSSION and CONCLUSION In this study, we proposed a new approach to acquire high resolution MT image in clinically reasonable time (FOV = 192×192×53 mm^3; 0.6 mm^3 isotropic resolution; 6.04 min) and provide similar quality MTR map to conventional MT imaging. The method utilizes a variable density MT pulse application scheme, where a higher density of MT pulses is applied in the center of the k-space and sparsely applied MT pulses in the outer k-space lines, to reduce SAR as well as scan time. The proposed high resolution imaging protocol provides high quality images and clearly delineates small structures in the MTR map. Compared to conventional MTR (Fig. 2A), proposed vdMTR shows (Fig. 2B) a little blurred image result due to MT induced signal discontinuity between center and outer k-space region. However, the capability to increase resolution in shorter acquisition time can compensate degraded image quality problem. As shown in Fig. 4, the proposed method generates high resolution and high quality MTR map in reasonable scan time and these features make vdMT method appealing for clinical applications in UHF where myelination is being assessed. Future extension of the vdMT sequence to a variable TR (combined with variable flip angle) can reduce aforementioned image blurring problem. Variable TR approach has the additional advantage of reducing scan time.

References: [1] Metcalf, 2010, J Neuroimaging, 20:141, [2] Balaban and Ceckler, 1992 [3] Gass et al., 1994 [4] Ropele, 2005, MRM, 53:134