Background-Suppressed Myelin Water Imaging

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Introduction:

Myelin water imaging (MWI) measures signals from water molecules in the gap of neighboring myelin layers in white matter. It has been shown that this fraction of water has shorter T_2 and T_2^* (1-2) than other water. In conventional MWI, multiple exponential decays from different water components are measured by multi-echo GRE or SE and then fitted using non-negative least-square fitting to estimate the distribution of transverse relaxations (3). However, the fitting process is ill-conditioned and the resulting MWI is sensitive to noise and artifacts (3,4). In this abstract, we propose a novel approach of acquiring a myelin water image. The method assumes that the myelin water has shorter T_1 (6-10) than the other water components and utilizes a double inversion RF pulse sequence to suppress long T_1 water signal. We investigate the signal characteristic of the short T_1 signal to confirm that the signal is primarily from the myelin water. This new method generates substantially improved myelin water images.

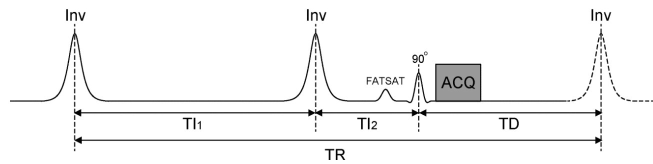

Fig.1: Double inversion sequence for BS-MWI

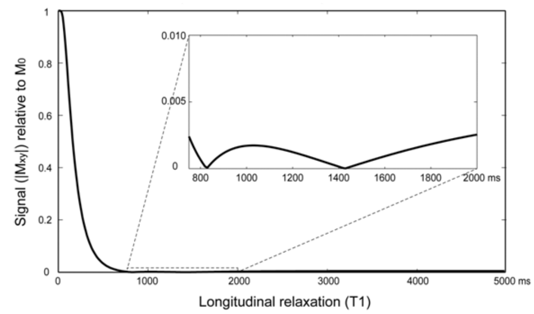

Fig.2: Suppression of long T_1 components

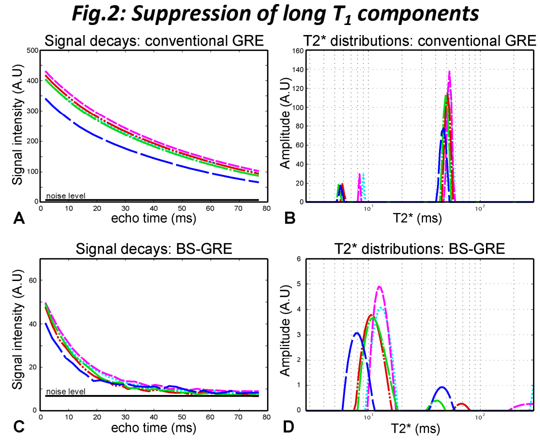

Fig.3: Signal decays in conv. GRE (A) and BS-GRE (C). The resulting T_2* distributions in conv. GRE (B) and BS-GRE (D). 5 different WM ROIs.

Methods:

To selectively suppress a range of long T_1 water components, a double inversion RF pair (Background-Suppression; BS) was used (Fig. 1). The three intervals (TI_1, TI_2, TD) were chosen to have large signal for $T_1 \leq 200$ ms and substantially suppressed signal from long T_1 (0.3 % or less for $750 \leq T_1 \leq 2000$ ms, and 0.5% or less for 2000 ms $\leq T_1 \leq 5000$ ms) (Fig. 2). The resulting parameters were $TI_1/TI_2/TD$ = 560/220/380 ms. For MRI scans, 5 subjects (mean age = 33 ± 4 years; IRB approved) were scanned at 3 T (Siemens). The following scans were performed. **Scan 1** Background-Suppressed MWI using a double inversion prepared multi-echo GRE sequence (TR = 1160 ms, $TI_1/TI_2/TD$ = 560/220/380 ms, TE = 1.85:2.42:77 ms, and resolution = 1.88 x 1.88 x 3mm^3). **Scan 2** Conventional MWI using a multi-echo GRE sequence of a long TR (= 1160 ms): The same sequence structure as Scan 1 with no inversion RF pulse. **Scan 3** Conventional MWI using a multi-echo GRE sequence of a short TR (= 97ms): 12 averages to have the total scan time as Scan 1 and Scan 2. **Scan 4** High-resolution BS-MWI using a single but long readout: the same timing as Scan 1, resolution = 1 x 1 x 3 mm^3, readout duration = 10 ms, 2 avg, and 10 min. To characterize the multi-component T_2^* decays in the BS-GRE (Scan 1) and the conventional GRE (Scan 3) data, an ROI analysis (five ROIs) was performed. Scan 2 showed artifacts at late echoes in some subjects and was not used for the analysis. The distribution of the multiple components was estimated by fitting the mean decay curve with multiple exponential T_2^* decays using regularized nonnegative least square fitting (3). Myelin water fraction was calculated for Scan 3 ($T^*_{2\,myelin\_water}$ < 20 ms) and compared to BS-MWI images.

Results:

Compared to the conventional GRE (Scan 3), the BS-GRE shows much rapid signal drop reaching a noise level at late echoes (Figs. 3A and 3C). The T_2^* distribution (Figs. 3B and 3D) confirms that short T_2^*, which corresponds to myelin water (T_2^* < 20 ms), dominates the signal in the BS-GRE. The mean myelin water fraction (5 subjects, 5 ROIs) is 5.9 ± 1.4 % in the conventional GRE whereas it is 91.4 ± 3.2 % in the BS-GRE. In Fig. 4, the result of the myelin water fraction from the conventional MWI is compared to the BS-MWI image (average of the first five echoes). Compared to the conventional MWI image, the BS-MWI image show less speckle artifacts providing a superior image quality. A high-resolution BS-MWI image (Fig. 5; corrected for a coil sensitivity profile) shows a high quality myelin water image.

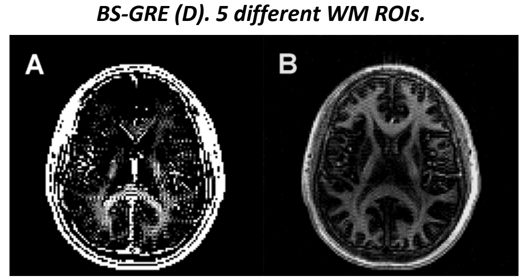

Fig.4: (A)Conventional MWI and (B) BS- MWI.

Discussion and Conclusion:

Here, we presented a new sequence that selectively suppressed long T_1 signal in WM and demonstrated that the suppression left (primarily) short T_2^* signal, in the range of the myelin water. Hence, the new method generates a myelin water image. In the BS-MWI images, a few other areas, that are unrelated to the myelin water, are also visible. For example, arteries are highlighted due to the inflow effects. The skull area has high signal which might be from an imperfect fat saturation. However, in white matter, the primary signal is from the myelin water. This new method may provide clinically useful information for the diagnosis of myelin integrity.

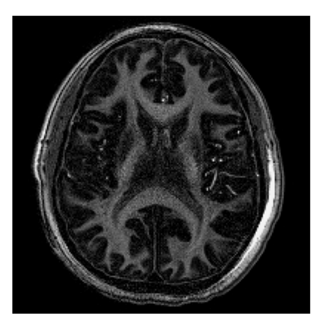

Fig.5: High resolution BS-MWI

References:[1] Mackay, A, MRM, 1994, (31) 673-677 [2] Du, Y.P., MRM, 2007, (58) 865-870 [3] Whittall, K.P., JMR, 1989, (84) 134-152 [4] Cover, K.S., Rev Sci Instrum, 2008, (79) 055106-055101 [6] Does, M.D., MRM, 2002, (47) 274-283 [7] Koenig, S.H., MRM, 1990, (14) 482-495 [8] Lancaster, J.L., JMRI, 2002, (17) 1-10 [9] Stanisz, G.J., MRM, 2005, (54) 507-512 [10] Labadie, C., 17th ISMRM, 2009, p.3210