Myelin Water Imaging using Direct Visualization of Short Transverse Relaxation Time Component (ViSTa) at 7T

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Introduction

Myelin Water Imaging (MWI) is a potential biomarker for the diagnosis and prognosis of neurological disorders such as multiple sclerosis [1]. A recently developed method, ViSTa (Direct Visualization of Short Transverse relaxation time component; previously, background-suppressed MWI [2, 3]), has demonstrated that myelin water signal can be acquired by suppressing long T_1 water signals from axonal and extracellular water. In this study, ViSTa was applied at ultra-high field (7T) and the results were compared with those from 3T.

Method

***Experiments*:** Three subjects (age: 27 ± 6) were scanned at 3T and 7T (IRB approved). Two ViSTa sequences that have different double inversion timings have been developed for the suppression of long T_1 signals. The first one had TR = 1160 ms with TI_1 = 560 ms, TI_2 = 220 ms, and TD = 380 ms, which were the same as in the previous study [2]. At 7T, the T_1 of white matter increases [4]. This change allows us to design a new ViSTA timing with a larger magnetization at short T1 and a modified long T1 suppression (Figure 1). The newly optimized timing was TI_1 = 700 ms, TI_2 = 280 ms, TD = 460 ms, and TR = 1440 ms assuming axonal and extracellular water has T_1 longer than 1 sec [5]. When compared with the previous ViSTa timing (TR = 1160 ms), the signal at the nominal myelin water T_1 (approximately =100 to 120 ms at 3T and 7T [6]) increases from 0.69 into 0.86. For the experiment, the sequence parameters were as follows: FOV = 220 x 220 mm^2, resolution = 1.375 x 1.375 mm^2, slice thickness = 3 mm, TE = 1.44 ms to 71.81 ms (echo spacing = 2.27 ms), number of echoes = 32, flip angle = 90° (duration = 1 ms; sinc), matrix size = 160 x 160, bandwidth = 1560 Hz/pixel. A non-selective hyperbolic secant pulse (duration = 10.24 ms and bandwidth = 1 kHz) was used for the inversion pulses. Data were acquired twice and averaged. A multi-echo GRE sequences was also obtained with the same parameters with ViSTa sequences, except TR was 75 ms for two subjects and 100 ms for the other subject, and the flip angles was 5°. To reduce the impact of B_1 inhomogeneity at 7T, the transmit reference voltage was calculated locally for splenium, which was used as an ROI in the analysis. ***Analysis*:** The T_2^* value was estimated using a nonlinear curve fitting (Levenberg–Marquardt algorithm) [7, 8] for the average signal on the ROI. The T_2^* distributions were obtained using a nonnegative least-square (NNLS) fitting method [9] for the same signal. In the T_2^* distributions, the signal ratio between the T2* signals shorter than 15 ms and the total signal, referred to as Ratio15, was measured. The fraction of the short T_2^* signals relative to total water signal (MWF) was calculated as follows: the first echo ViSTa image was divided by the first echo GRE image. Then, the result was multiplied by the scale factor to compensate for T_1- and T_2^*-weighting in GRE and ViSTa. The scale factor was (GRE T_1-weight x GRE T_2^*-weight)/(ViSTa T_1-weight x ViSTa T_2^*-weight). The nominal T_1 and T_2^* in GRE at 3T were assumed to be 800 ms and 50 ms and nominal T_1 and T_2^* in ViSTa at 3T were assumed to be 118 ms and 10 ms [6]. At 7T, those values in GRE were assumed to be 1200 ms and 30 ms and values in ViSTa were 106 ms and 10 ms [6].

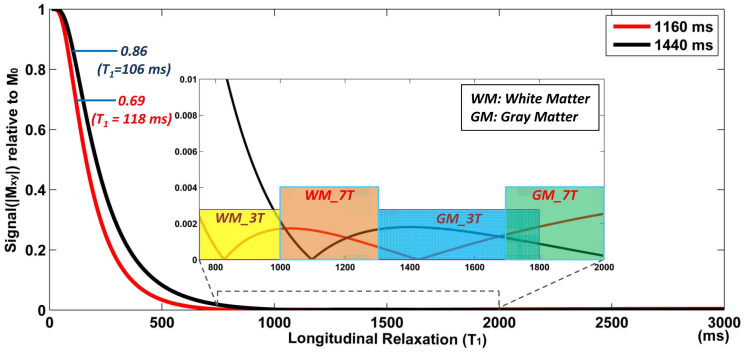

Figure 1 Transverse magnetization as a function of T_1 in two ViSTa sequences

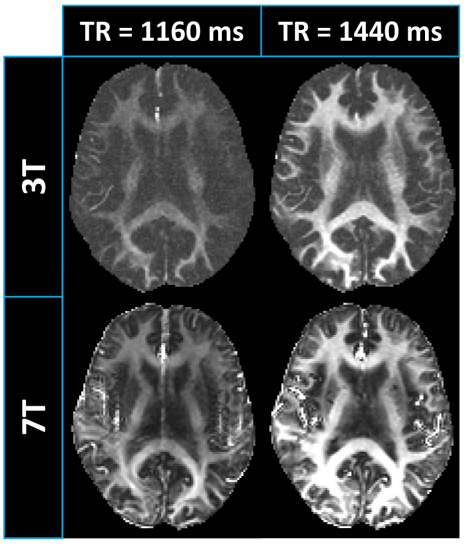

Figure 2 ViSTa images at 3T and 7T

Results and Discussion

Figure 2 shows the 1st echo ViSTa images at 3T and 7T. 7T shows better image quality with higher SNR. When the signals in ROI were compared quantitatively, the SNR at 7T is about three times higher than the SNR at 3T (Table 1). The T_2^* of ViSTa signal ranges from 7.40 to 11.60 ms at 3T [10]. The Ratio15s are greater than 80% in all field strength and TRs. The Ratio15s at 7T decreased in comparison with the Ratio15s at 3T suggesting larger contribution of long T_1 signals at 7T. The Ratio15s in TR = 1440 ms is lower than those in TR = 1160 ms also suggesting larger contribution of long T_1 signals at the longer TR. Different from our expectation, the MWFs at 7T (2.9% from 1160 ms) showed almost 60% of the MWFs at 3T (5.2% from 1160 ms). This result may have caused by the inaccurate flip angle of GRE due to the field inhomogeneity inducing a larger signal at the 7T GRE images. This explanation is supported by 5.3 times higher SNR of the 7T GRE data compared to the 3T GRE data. This increase cannot be explained solely by the field strength difference between 3T and 7T and may be explained by a larger flip angle applied at the 7 T scan. When the ViSTa sequence was simulated for B_1 inhomogeneity, it showed relatively smaller variation because of the use of adiabatic inversion pulse and a 90° excitation RF pulse.

Field strength	3T		7T	
TR [ms]	1160	1440	1160	1440
SNR for 1st echo	16.87 (0.99)	26.24 (1.69)	44.09 (3.03)	70.28 (4.37)
T_2^* [ms]	7.74 (0.28)	11.60 (0.35)	8.15 (0.31)	7.40 (0.13)
Ratio15 [%]	93.82 (4.72)	87.97 (2.71)	86.19 (5.19)	80.90 (0.99)

Table 1 Comparison of results at 3T and 7T (Mean Value (STD))

Conclusion

The ViSTa images at 7T showed a higher SNR than at 3T, demonstrating potential of using ViSTa at 7T to improve resolution. The B_1 inhomogeneity sets a primary challenge for quantification and needs a new approach for an accurate quantification.

References

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