Measurement of *in vivo* multi-component T2 relaxation times using head and phased array coils at 1.5T and 3T

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Introduction: Accurate measurement and quantification of the myelin water content is important for patients with multiple sclerosis (MS). Previous studies have shown the existence of multi-component T2 relaxation decay curves in biological tissue as an indicator of compartmentation [1] and increased total water contents and decreased myelin water in normal appearing white matter for patients with MS relative to normal controls [2]. The CPMG sequence has been widely used to acquire multi-echo data set, but the coverage of this sequence is limited to a single-slice because it uses slice selective 180° refocusing trains. This study was designed to evaluate a multi-slice multi-echo T2-prepared spiral imaging sequence at 1.5T and 3T and to investigate the effect of the use of a commercially available receive-only 8-channel phased array coil relative to the conventional volume head coil for quantification of T2 relaxation times.

Methods: MR images were acquired with 1.5T and 3T GE Signa scanners equipped with both quadrature volume head coil and 8-channel phased array coil. A commercial T2 phantom (108/109 msec at 1.5/3T, 296K) was used to test the accuracy and reproducibility of measure T2 values. Nine normal controls (mean age 27.2 years, range of 22 – 32 years) and two relapsing remitting MS (RRMS) patients (36 and 43 years) were scanned. All subjects gave their written informed consent. A multi-slice multi-echo T2-prepared spiral sequence was used in this study to acquire 12-echo data [3]. In brief, the T2-preparation portion of the sequence consisted of a nonselective 90° tip-down pulse, a train of equally spaced (6 msec) composite 180° hard pulses (90_x-180_y-90_x) with MLEV radio frequency (RF) recycling pattern, and a hard -90° tip-up pulse. Large gradient spoilers following the tip-up pulse dephase any remaining transverse magnetization. Image acquisition follows the T2-preparation and includes a spectral-spatial pulse and spiral readout for each prescribed section. An RF cycling scheme was used to mitigate the effects of T1 recovery between the T2 preparation and the multi-slice spiral readouts. Nonlinearly sampled 12-echo MR imaging parameters were TR = 2500 msec, TE = 6, 17, 28, 38, 49, 60, 70, 92, 124, 177, 220 and 294 msec, 240 × 240 mm field of view, NEX = 8, 4096 points with 4 spiral interleaves, 128 × 128 matrix, resulting in an effective resolution of 2 × 2 mm, 10/0 mm thickness/skip and 8 slices (scan time of 16 min). The 12-echo data were fitted by a distribution of T2 values using a nonnegative least square (NNLS) algorithm [4]. The solution of the NNLS algorithm was iteratively regularized such that the ratio of chi-square misfit between the regularized and unregularized solution was less than 1%. The T2 axis was partitioned into 80 logarithmically spaced compartments between 15 and 2000 msec. Estimated T2 components below a specific threshold (peak area < 3% of total water) were ignored to eliminate the dependence of the fit to the noise. A median filter with a kernel of size of 3 was applied to the original images before fitting. Three normal controls were scanned twice using the 8-channel phased array coil at both field strengths.

Results: The mean (standard deviation (SD)) estimated T2 peak locations for the T2 phantom from 3 scans were 101(4.6)/104(0) and 104(0)/104(0) at 1.5T/3T for head coil and 8-channel phased array coil, respectively. Table 1 shows the mean (SD) myelin fraction (defined as the ratio between peak areas for the short T2 component (T2 < 50 msec) and total water (%)) for various white and gray matter ROIs for normal controls using the 8-channel phased array coil. The coefficients of variation were 0.04 – 0.10 in the white matter for normal controls from both field strengths. Figure 1 shows myelin fraction maps (MFM) overlaid on anatomical images with TE = 17 msec using both coils at 3T for normal controls. It was also observed that the performance of the T2 quantification was poor when the volume head coil was used at 3T (Figure 1 (b)). This was particularly true for the cortex due to an overestimation of the short T2 component in that region. This could be explained by the larger variations from multi-echo signal intensity that were induced by poor performance of the 180° refocusing trains at the edge of the coil. Figure 2 shows the same map for the RRMS patient. It was observed that there was reduced myelin fraction within the MS lesions compared to surrounding normal appearing white matter.

Discussion and Conclusion: The estimated T2 relaxation times were accurate and reproducible from the phantom that had known T2 relaxation times. It was found that short T2 components were mainly observed within the white matter and that the mean fraction of short T2 water components (i.e. myelin water) was 7 – 12% of total water for normal controls. This value agrees with previous study using single-section 32-echo CPMG sequence [2]. It was also found that the performance of 180° refocusing trains was more spatially uniform for the 8-channel phased array coil than the head coil, particularly at 3T. This may be explained by the receive-only phased array coil using the more uniform body coil for transmission while the head coil is used for both transmission and reception.

Table 1 The mean myelin fraction (%) for various white and gray matter ROIs using the 8-channel phased array coil at 1.5T and 3T from normal controls.

ROIs	1.5T	3T
Frontal white matter	7.0 (0.4)	10.1 (0.3)
Parietal white matter	7.6 (0.7)	9.7 (0.8)
Occipital white matter	7.7 (1.9)	11.4 (1.9)
Corpus callosum	7.3 (1.6)	12.1 (1.4)
Internal capsules	9.0 (1.7)	12.3 (1.2)
Caudate nucleus (head)	2.4 (1.3)	4.4 (1.0)
Putaman	3.6 (1.5)	5.6 (1.5)
Thalamus	4.5 (0.5)	4.7 (1.3)

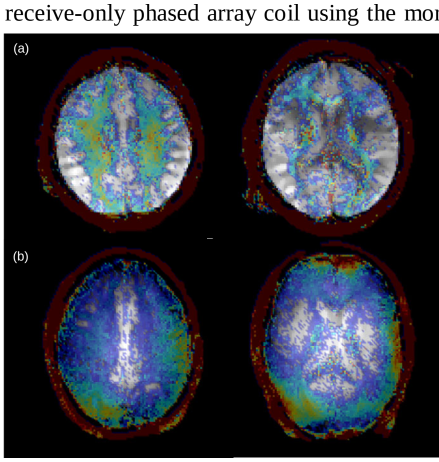

Figure 1. MFM overlaid on TE = 17ms images using 8-ch phased array coil (a) and head coil (b) at 3T for controls.

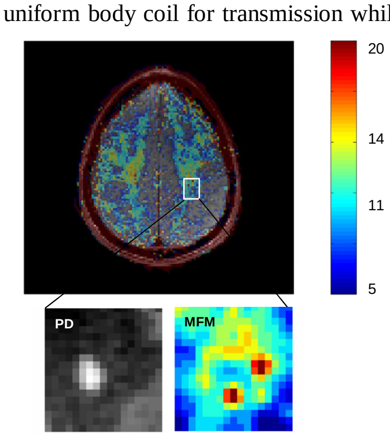

Figure 2. MFM overlaid on TE = 17ms image using 8-channel phased array coil at 3T for a RRMS patient. One MS lesion based on PD images is shown on the bottom left enlarged frame.

References

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