Standardized Structural Magnetic Resonance Imaging in Multi-Centre Studies Using Quantitative T1 and T2 Imaging

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INTRODUCTION: Increasingly, investigative MRI studies are becoming multi-centre and longitudinal in nature, with data acquired at multiple imaging centres or across multiple time-points and subsequently pooled for analysis. Such studies facilitate large study populations infeasible at a single centre, as well as eliminate the confounding effects of inter-subject heterogeneity inherent in cross-sectional studies. However, a significant challenge is ensuring uniformity (or standardization) of image quality (in terms of tissue contrast and noise characteristics) so that meaningful inferences can be drawn. The oft-used approach, therefore, is to use a set of common acquisition sequences with carefully matched acquisition parameters (echo time, *TE*, repetition time, *TR*, flip angle, α, etc.). Unfortunately, as these parameters are necessarily dictated by the least state-of-the-art system, this approach sacrifices the potential gains in signal-to-noise ratio (*SNR*) efficiency afforded by the improved gradient performance and dedicated multi-channel RF coils available on newer systems. Here we demonstrate an alternative approach to standardization, voxel-wise determination, or mapping, of the intrinsic T_1 and T_2 relaxation times. In the context of a three-centre autism study (the MRC UK AIMS program), we demonstrate high intra and inter-site reproducibility of the T_1 and T_2 measures using the DESPOT1 and DESPOT2 relaxometry methods[1].

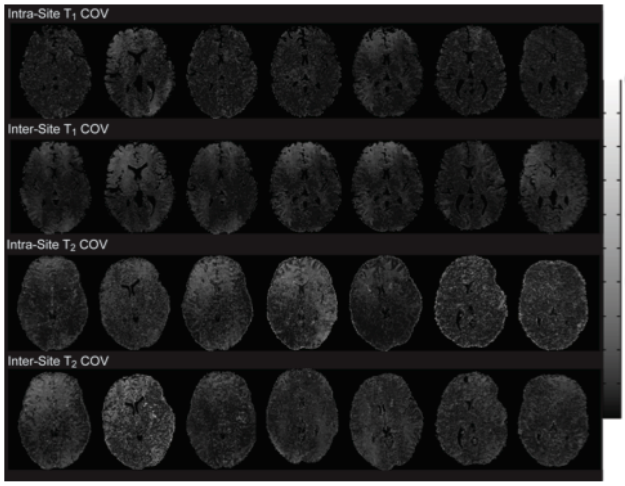
METHODS: 7 healthy individuals (4 male, 3 female, 22-34 years of age) were recruited for the study. All volunteers were scanned at each imaging centre at 1.5T (with two sagitally-oriented T_1 and T_2 maps acquired during each scan session) yielding six inter-site T_1 and T_2 maps per volunteer. Additionally, the four male volunteers were scanned on a further two occasions at center #1 (again, two T_1 and T_2 maps were acquired on each visit) and the three female volunteers were scanned on a further two occasions at center #3, yielding six intra-site T_1 and T_2 maps per volunteer. A summary of the SPGR (DESPOT1) and SSFP (DESPOT2) acquisition parameters are shown in Table 1. Total imaging time was similar at each centre, requiring just 12 minutes for each T_1 and T_2 map pair, comparable to conventional T_1 or T_2-*weighted* MP-RAGE or IR-SPGR acquisitions.

Following acquisition, intra and inter session images were non-linearly co-registered[2] and the T_1 and T_2 maps calculated. Reproducibility was assessed by calculating the voxel-wise intra and inter-site coefficients of variation (CoV) and averaging these values over all brain voxels for each volunteer. Further, the T_1 and T_2 maps of each volunteer were non-linearly co-registered and smoothed with a 3D Gaussian kernel (full-width-at-half-max value = 5mm). Paired *t*-Tests were then performed voxel-wise across the data acquired at each site as well as between the repeated scans performed at the same site.

Centre	Manufacturer	Field of View	Image Matrix	TE (ms)	TR (ms)	Flip Angle	Bandwidth
#1	GE	24 cm² x 17 cm	200² x 140	1.6	8.5	4, 15	107
#2	GE	24 cm² x 17 cm	200² x 140	1.6	8.5	4, 15	107
#3	Siemens	24 cm² x 17 cm	192² x 140	3.9	8.5	4, 15	160
#1	GE	24 cm² x 17 cm	200² x 140	2.3	4.5	15, 70	833
#2	GE	24 cm² x 17 cm	200² x 140	2.4	4.7	15, 70	833
#3	Siemens	24 cm² x 17 cm	192² x 140	2.3	4.6	15, 70	950

Table 1: Acquisition parameters for DESPOT1 (white background) and DESPOT2 (light gray background) at each imaging centre.

RESULTS: Representative axial slices through the intra and inter-site T_1 and T_2 CoV maps of all volunteers are shown in Fig. 1. Mean CoV values calculated from each individual are shown in Table 2 with average intra and inter-site values of 0.064 and 0.069 for T_1 and 0.079 and 0.083 for T_2. Figure 2 contains representative axial slices through the voxel-wise intra and inter-session paired *t*-Test maps. Even without false discovery rate (FDR) correction, no voxels were found in the *t*-Test maps with a p value lower than 0.1m demonstrating no significant differences between the T_1 or T_2 measures.



	# Brain Voxels	Intra-Site T_1	Inter-Site T_1	Intra-Site T_2	Inter-Site T_2
Vol. #1	931413	6.3 (0.34)	7.6 (0.52)	8.2 (0.72)	8.4 (0.92)
Vol. #2	1336992	7.1 (0.43)	8.5 (0.56)	9.3 (0.56)	10.2 (0.82)
Vol. #3	1476789	5.4 (0.32)	5.8 (0.45)	8.1 (0.66)	8.8 (0.81)
Vol. #4	1482812	6.1 (0.37)	6.7 (0.51)	7.3 (0.65)	7.6 (0.72)
Vol. #5	1452150	6.5 (0.35)	6.6 (0.49)	7.4 (0.65)	7.9 (0.78)
Vol. #6	1366925	5.9 (0.33)	5.6 (0.44)	7.2 (0.64)	7.3 (0.79)
Vol. #7	1374312	6.1 (0.36)	7.9 (0.46)	7.2 (0.67)	7.9 (0.81)
Average	**9421393**	**6.4 (0.52)**	**6.8 (0.67)**	**7.9 (0.71)**	**8.3 (0.92)**

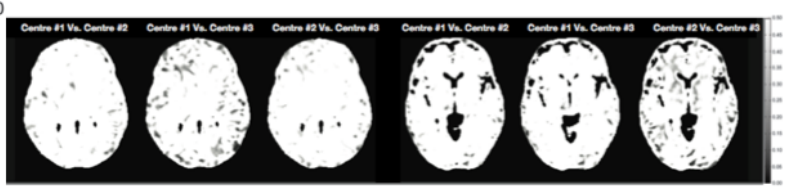


Figure 1 (Left): Axial slices through the calculated T_1 and T_2 CoV Maps of each of the 7 volunteers. Mean values averaged over all brain voxels are shown in **Table 1 (Upper Right)**. **Figure 2 (Lower Right):** Axial slices through the intra and inter-site voxel-wise t-Test maps. No voxels with a significant difference ($P < 0.1$ FDR uncorrected) were found.

DISCUSSION / CONCLUSIONS: In this study we demonstrated the potential of rapid relaxometry for standardizing structural scanning in multicentre and longitudinal studies. DESPOT1 and DESPOT2 permit whole-brain, high-resolution T_1 and T_2 mapping with a combined imaging time of less than 12 minutes and with mean intra and inter-site coefficient of variations of 0.064 and 0.069 for T_1 and 0.079 and 0.083 for T_2. The methods are easy to implement (as they utilize imaging sequences common amongst major vendors) and do not impose a large computational burden for post-processing.

REFERENCES: [1] Deoni SCL. et al. Magn. Reson. Med. 2003; 46:515-526, [2] Collins DL. et al. J Comput. Assist. Tomogr. 1994; 18: 192-205.