Optimisation of T_2^*-weighted MRI for differential diagnosis of MS at clinical field strengths

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Introduction: 7T T2*-weighted MRI has been shown to allow differentiation between MS lesions and microangiopathic white-matter (WM) lesions via the presence of a visible central vein[1], and accurately predicts eventual diagnosis of MS in patients who were initially undiagnosed and referred for further testing[2]. However, the limited availability of 7T systems necessitates the translation of this technique to lower field. The aim of this work is to increase the sensitivity of the technique at 3T and 7T, using SNR measurements and simulations to predict optimal scanning parameters. Patients with confirmed MS were scanned at both field strengths, using the optimised sequences as well as those used in previous work[1,2]; the optimised sequences are compared theoretically and experimentally.

Methods: 3 patients with clinically definite MS and 2 healthy volunteers were recruited. Simulations: The signal change due to the presence of a vessel in a voxel was simulated for a range of vessel radii (1 – 700 μm) and orientations to the static field. This was repeated over the range of echo times and voxel volumes and shapes (8 difference aspect ratios for each volume), for venous and arterial blood with and without the use of exogenous contrast agent (Gadolinium) for magnitude images and SWI. The TE and voxel dimensions which produced the highest sensitivity to veins (while keeping low the sensitivity to arteries, and reducing the inherent bias towards detection of veins perpendicular to the static field) were determined. MR scanning: 3T scans were acquired using a Philips Acheiva 3 T system with a whole-body gradient set, whole-body transmit coil and 8-channel SENSE rf receive coil. Scanning at 7 T was performed using a Philips Acheiva 7 T scanner with whole-body gradient set, head-only transmit coil and 16-channel SENSE rf receive coil (NovaMedical). SNR was measured in healthy volunteers for a range of TEs (5 – 50 ms) and voxel sizes (0.043 – 0.512 mm^3) and used to calculate a threshold for the proportional signal change necessary to allow depiction of a vessel. All T2* sequences used a 3D TFE acquisition, with four overlapping and interleaved imaging stacks to reduce acquisition time. The original (pre-optimisation) sequences were those used in Tallantyre et al[1] [TE = 20 ms, TR = 150 ms, 0.8-mm isotropic voxels at 3T and 0.5-mm isotropic voxels at 7T, acquisition time 8.8 and 7.9 min, respectively]. The final optimised sequences which were used to scan MS patients used 15-ms TE and 0.32 x 0.32 x 0.9 mm^3 voxels (7T) and 25-ms TE, 0.55 x 0.55 x 1.05 mm^3 voxels (3T). A Fluid-Attenuated Inversion-Recovery (FLAIR) sequence [1 x 1 x 2.5 mm^3 voxel size, TSE factor 27, 125-ms TE, 11-s TR, 2800-ms TI, 120° refocussing pulses, acquisition time 6 min] was also used to obtain images of the 3 MS patients. Lesions were identified on the 3T FLAIR images and it was determined whether each of the lesions were visible on each T2* image; lesion volume and the presence or absence of a visible central vessel was recorded.

Results: The simulations predicted the optimal TE and voxel dimensions to be 15 ms and 0.32 x 0.32 x 0.90 mm^3 at 7T, and 25 ms, 0.55 x 0.55 x 1.05 mm^3 at 7T. This decreased the cross-sectional area of the smallest detectable vein from 0.015 mm^3 to 0.014 mm^3 at 7T, and 0.071 mm^3 to 0.062 mm^3 at 3T, and considerably decreased the sensitivity to vessel orientation. Neither the creation of SWI images nor the administration of Gadolinium were found to be useful for this technique. A total of 214 lesions was detected on the 3T FLAIR images (mean 71 per patient, range 41 – 114; mean lesion volume 138 mm^3)**.** The original sequences allowed detection of 53% (3T) and 66% (7T) of theses lesions; the optimised sequences demonstrated 71% (3T) and 72% (7T). A vessel could be visualised in 56% (3T, mean across patients 55%, range 46-68%) and 89% (7T, mean 85%, range 81-92%) of visible lesions in images acquired with the original sequences, and in 82% (3T, mean 80%, range 75-83%) and 95% (7T, mean 95%, range 90-98%) using the optimised sequences (Figure 1).

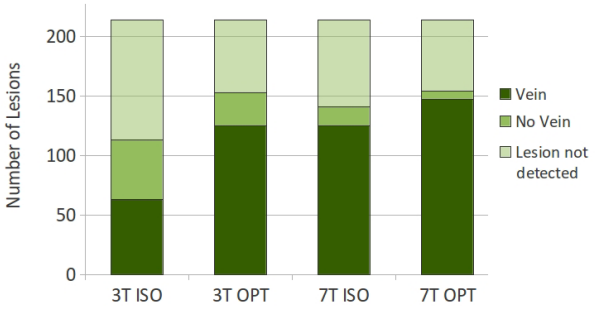

Figure 1 *– Number of detected lesions with and without detectable central veins, at 3T and 7T, for images acquired with previously used sequences (ISO) and newly optimised sequences (OPT)*

Discussion: The optimisations discussed here have considerably increased the sensitivity of T2*-weighted imaging to small veins. The sensitivity of the optimised 3T sequence is now comparable to that of the previously used 7T sequence, which has been shown to allow discrimination between lesions caused my demyelination and ischaemic lesions and to predict eventual diagnosis of MS in patients for whom diagnosis is initially unclear [2] , suggesting the possibility of using this technique clinically for diagnosis of MS. Future work will assess the ability of the 3T optimised sequence to predict diagnosis of MS in undiagnosed patients.

References: [1] Tallantyre EC, Neurology 2011; 76: 534 [2] Mistry N, A single 7T MRI brain scan accurately predicts eventual diagnosis of MS in cases with initial diagnostic uncertainty. Abstract. JNNP; IN PRESS**.** **Acknowledgements:** MRC, MS Society UK