Multimodal registration to improve the detection of cortical lesions in Multiple Sclerosis utilised both 7T and 3T MRI

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Introduction: Multiple Sclerosis MS has classically been regarded as a white matter disorder that manifests as acute focal inflammatory demyelination and axonal loss with limited remyelination. However, histological studies have shown that a significant number of lesions are located within the cerebral cortex or at the border between the cortex and subcortical white matter. These cortical lesions have been correlated with physical and neuropsychological deficits in patients with MS[1]. Intracortical lesions are difficult to detect in MRI, this is thought to be due to their small spatial extent, complex geometry and low levels of inflammations causing low contrast between the lesions and their surrounding grey matter (GM)[2]. The higher signal to noise ratio available at ultra high (7T) magnetic field allows a higher (~0.5 mm) spatial resolution to be achieved. In addition, the change in relaxation rates at high field may allow for the introduction of novel contrast between tissues. This study investigates which combination of pulse sequences at high magnetic field strength will maximise the likelihood of depicting small lesions associated with the cerebral cortex. However, localising the same potential cortical lesion across field strengths and imaging protocols is difficult, reducing confidence in lesion detection and making sequence comparison more difficult. Therefore the specific aim of this work presented here was to explore cooregistration of images between field strengths and between sequences.

Material and methods: 18 MS patients were recruited from the Queen's Medical Centre and scanned using 3T and 7T Philips Acheiva scanners after they gave an informed consent.

The scan protocol at 7T included 3D MPRAGE (0.5mm isotropic resolution; 192x164x100 mm^3 FOV; TE=6.6 ms; TR=14 ms; TI=1051 ms; total scan time=11.33 min), FLAIR (0.6x0.6x2 mm^3 resolution;192x163x72 mm^3 FOV; TE= 80 ms; TR=1500 ms; TI= 2800; total scan time 5 min), 3D T_2* (0.5 mm isotropic resolution; 192x164x100 mm^3 FOV; TE=20 ms; TR=150 ms; flip angle=14 ; total scan time 8:48 min)and 3D T_2 (1mm isotropic resolution; 192x164x100mm^3 FOV; TE=245 ms; TR=2500 ms; flip angle= 90 ; total scan time 7:45 min) weighted pulse sequences.

The scan protocol at 3T included 3D MP-RAGE (0.8 mm isotropic resolution; 205x205x147 mm^3 FOV; TE=2.3 ms; TR=7.7 ms; TI=945.6 ms; total scan time=9.59 min), FLAIR (1.0x1.0x2.5 mm^3 resolution; 256x204x 140 mm^3 FOV; TE=125 ms; TR=11000 ms; TI=2800 ms; total scan time 5.52 min), 3D T_2* (0.8 mm isotropic resolution;192x163x148 mm^3 FOV; TE=20 ms; TR=150 ms; flip angle = 14 ; total scan time 7.11 min), DIR (1x1x 2 mm^3 resolution; 256x192x76 mm^3 FOV; TE=100 ms; TR=1100 ms; TI=3400 ms; total scan time 11:44 min), DTI (2 mm isotropic resolution; 224x224x104 mm^3 FOV; TE=57 ms; TR= 8483 ms; 32 directions; total scan time = 6.29 min)and 3D T_2 (1 mm isotropic resolution; 224x224x160 mm^3 FOV; TE= 185 ms; TR=2500 ms; flip angle = 90; total scan time 6:12 min) weighted pulse sequences.

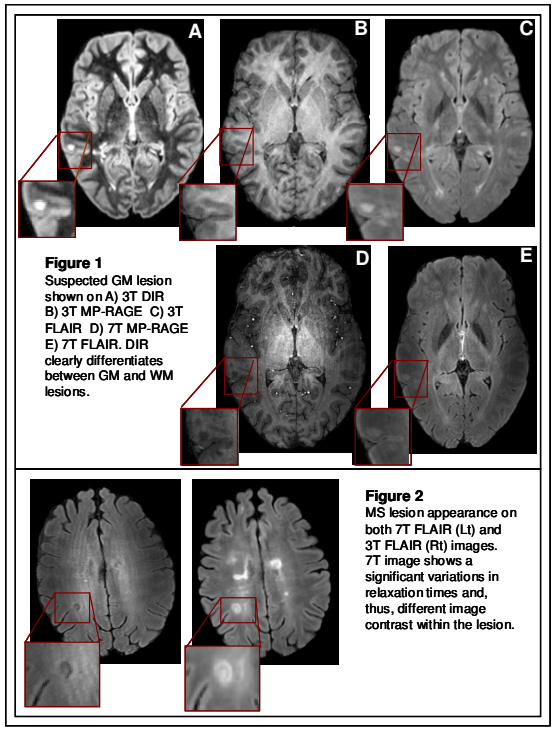

Figure 1 Suspected GM lesion shown on A) 3T DIR B) 3T MP-RAGE C) 3T FLAIR D) 7T MP-RAGE E) 7T FLAIR. DIR clearly differentiates between GM and WM lesions.

Figure 2 MS lesion appearance on both 7T FLAIR (Lt) and 3T FLAIR (Rt) images. 7T image shows a significant variations in relaxation times and, thus, different image contrast within the lesion.

Following image acquisition, image coregistration was performed using existing software packages FSL (www.fmrib.ox.ac.uk/fsl) and MRIcro (www.mricro.com). Prior to registration, the brain was extracted and common origin defined. The high resolution (0.5x0.5x0.5 mm^3) 7T MPRAGE was taken as the base image onto which the other images were co-registered. Furthermore, correction of the intensity variations on the 7T MPRAGE due to B_1 inhomogeneity was also done using SPM5.

Results: 10% of scans exhibited clear motion artefact and were excluded. Of the remaining scans, successful coregistration to the 7T MPRAGE was achieved in about 80%. The intensity correction improved the reliability of the cooregistration. Figure 1 shows a suspected GM lesion on multiple MR acquisitions. Figure 2 shows FLAIR images acquired at 3T and 7T again images are registered to the same space and the different appearance of white matter lesions is shown.

Discussion and conclusions: Cooregistration between 3T and 7T scans and between different sequences could be performed with a high success rate. This greatly improved the visual assessment of the same lesions across field strengths and sequences, increasing confidence in identification of potential cortical lesions, as demonstrated in Figure 1. Investigation into the failure of some scans to undergo successful cooregistration is ongoing.

DIR is an inherently low SNR sequence, this limits its spatial resolution and therefore its ability to characterise precisely the spatial distribution of lesions. In this work we have shown that grey matter effects detected using DIR at 3T are also visible using MPRAGE at 7T. The contrast mechanisms in MR imaging are also different at high field due to the difference in relaxation times. Here this has been shown in Figure 2 by the different appearance of white matter lesions between the FLAIR images at 3T and 7T.

In conclusion, cooregistration between field strengths and sequences increases confidence in describing lesions in MS. So it was important that all images were overlaid to a high standard and we have shown that this is possible between 3T and 7T scans acquired for this study. However, the combination of other high resolution imaging sequences at 7T show promise in providing an alternative protocol for detecting and investigating cortical lesions.

References: [1] Geurts JJ, et al. Radiology 236 (2005). [2] F. Nelson, et al. Am J Neuroradiol 28 (2007).