High-resolution in vivo imaging of cortical lesions in multiple sclerosis: a comparison of 3T and 7T

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Introduction: Although multiple sclerosis (MS) has traditionally been regarded as a white matter (WM) disorder, post-mortem studies have shown significant demyelination of the deep and cortical grey matter (GM), which has been suggested to account for the progressive disability seen in patients with MS. There has therefore been considerable interest in visualising these areas of grey-matter demyelination *in vivo*. The detection of cortical lesions with MRI is difficult due to their small spatial extent. It is likely that they also have similar relaxation times to GM. Furthermore, it is likely that the lesions have a similar relaxation time to GM. Double-inversion recovery has been found to be useful in the detection of these lesions[1,2], but is limited by the low SNR available at 3T. However, the high spatial resolution and enhanced image contrast mechansims available at 7T may improve the detection and classification of these lesions, enabling further study of their relationship to patient symptoms and disease progression. We have undertaken a comparison of imaging sequences at 3T and 7T in order to investigate the potential benefits of higher field strength and to identify which sequences are best suited to the study of cortical pathology.

Methods: 7T images were acquired using a Philips Acheiva system with a whole-body gradient set, 16-channel SENSE rf receive coil and head-only volume transmit coil. 3T images were acquired using a Philips Acheiva system with a whole-body gradient set, 8-channel SENSE recieve coil and a whole-body transmit coil. MS patients were recruited from Nottingham University Hospital's MS clinic. All subjects gave informed consent and the study received ethical approval from the Nottingham Research Ethics Committee. The scan protocol at 3T included DIR (1 x 1 x 2 mm^3 resolution; 256 x 192 x 60 mm^3 FOV; TE = 25 ms; TR = 11 s; Inversion times 3400 ms and 325 ms), acquired in 6 min 36 s, FLAIR (1 x 1 x 2.5 mm^3 resolution; 256 x 204 x 140 FOV; TE = 125 ms; TR = 11 s; Inversion time = 2800 ms) acquired in 5 min 52 s and MP-RAGE (0.8-mm isotropic resolution; 205 x 205 x 147 mm^3 FOV; TE = 2.3 ms; TR = 7.7 ms) acquired in 9 min 59 s. The scan protocol at 7T included FLAIR (192 x 163 x 72 mm^3 FOV; 0.6 x 0.6 x 2 mm^3 resolution; 36 slices; TR = 13.6 s; TE = 120 ms; Inversion time = 2800 ms), MP-RAGE (0.5-mm isotropic resolution; 192 x 164 x 100 mm^3 FOV; TR = 14 ms; TE = 6.6 ms) acquired in 11 min 53s and a T_2^*-weighted image (3D turbo-gradient-echo acquisition with 192 x 90 x 164 mm^3 FOV and 0.5-mm isotropic resolution. TR = 53 ms TE = 22 ms, 180 slices) acquired in 9 mins.

Results: Figure 1a shows a single slice from a 3T DIR image of one subject. Corresponding slices from 3T MP-RAGE (fig 1b), 3T FLAIR (fig 1c), 7T MP-RAGE (fig 1d) and 7T FLAIR (fig 1e), are also shown. The white arrows point to a single cortical lesion, and the inset images show close-ups of the lesion.

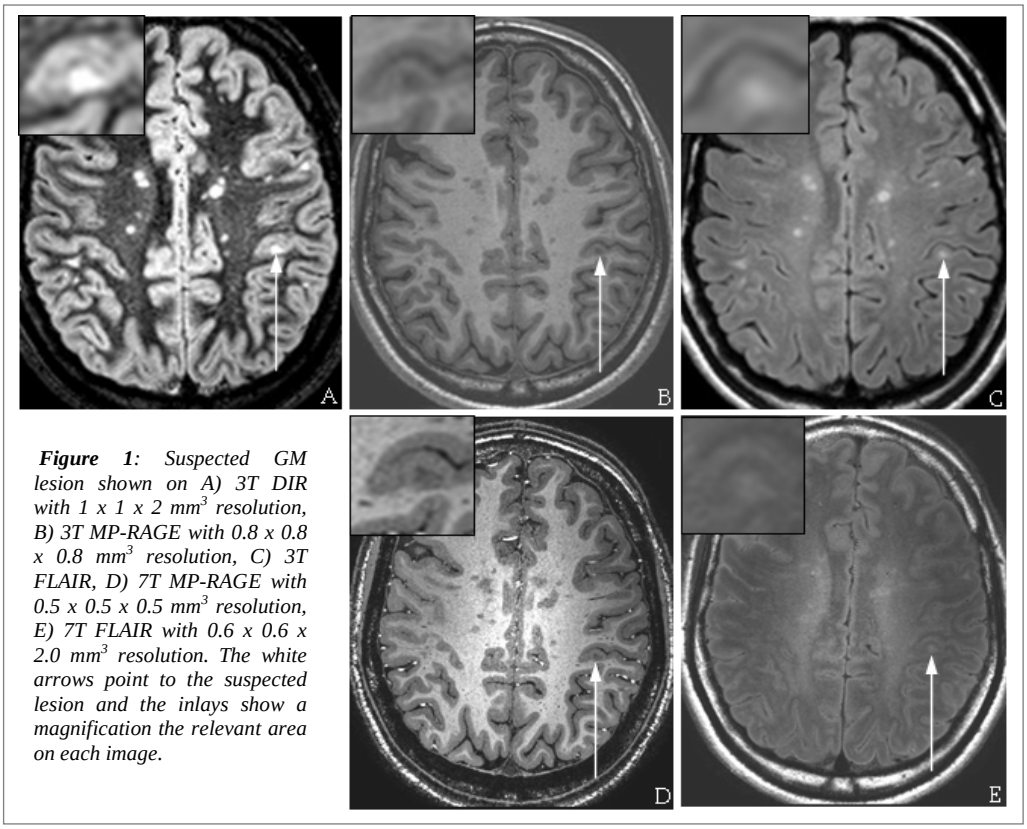

***Figure 1**: Suspected GM lesion shown on A) 3T DIR with 1 x 1 x 2 mm^3 resolution, B) 3T MP-RAGE with 0.8 x 0.8 x 0.8 mm^3 resolution, C) 3T FLAIR, D) 7T MP-RAGE with 0.5 x 0.5 x 0.5 mm^3 resolution, E) 7T FLAIR with 0.6 x 0.6 x 2.0 mm^3 resolution. The white arrows point to the suspected lesion and the inlays show a magnification the relevant area on each image.*

Discussion: The DIR image was found to be most useful in the identification of suspected cortical lesions, but due to the relatively poor resolution it was difficult to judge the extent and exact spatial location relative to cortical boundaries. Although the 7T FLAIR image offers higher resolution, the contrast is such that lesions are not easily visible. However, MP-RAGE images acquired at 7T show clearly the lesions and boundaries which, in combination with DIR, eases the classification of GM lesions.

Conclusion: The high resolution and improved contrast available in MR images acquired at 7T appears to be advantageous in the study of multiple sclerosis, specifically in the detection and classification of GM lesions. The use of 3T DIR and 7T MP-RAGE in tandem was found to be the most effective way of identifying and delineating these lesions, suggesting that development of the DIR sequence for use at 7T may prove to be a particularly useful tool in this area.

References: [1] Poonawalla AH, et al. Proc Intl Soc Mag Reson Med 15(2007). [2] Geurts JJ, et al. Radiology 2005;236:254.