

## Detection of cortical lesions in multiple sclerosis using FLAIR, DIR and ultra high field MPRAGE

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**Introduction:** Recent autopsy studies<sup>1</sup> have shown extensive grey matter (GM) demyelination in the brains of multiple sclerosis (MS) patients. It is tempting to consider that this cortical demyelination could account for chronic features of MS not readily explained by white matter (WM) demyelination. However, the ability to address this hypothesis has been hindered by the low sensitivity of MRI to cortical demyelination. This poor sensitivity may be attributed to several factors including the small volume of cortical lesions, their complex geometry and the similarity between relaxation times of lesions and grey matter. Despite the difficulties, recent improvements have been made using the dual inversion recovery (DIR) sequences<sup>2,3</sup>. DIR increases the detection rate of cortical lesions, however several authors have commented on its susceptibility to artefact<sup>2,4</sup>. In this study, we investigate whether cortical signal abnormality observed using 3T DIR is replicated in 3T FLAIR and high resolution MPRAGE images acquired at 7T. We show that ultra high field offers excellent contrast between lesions and GM. We also show that the increased spatial resolution at 7T makes accurate spatial characterisation of small cortical lesions possible.

**Methods:** Eleven subjects with demyelinating disease and eight healthy volunteers were recruited for the study. All subjects gave informed consent and the study had received ethical approval from the local research ethics committee.

7T images were acquired using an Achieva scanner (Philips Medical Systems), equipped with whole body gradients, a 16-channel receive coil and head only volume transmit coil (Nova Medical, Inc.). 3T images were acquired using an Achieva scanner (Philips Medical Systems) equipped with whole body gradients, an 8-channel receive coil and a whole-body transmit coil.

At 7T we used a T<sub>1</sub>-weighted MP-RAGE acquisition (192x164x100mm FOV, 0.5mm isotropic voxels, TE = 6.5ms, TR = 14ms, TI = 1033ms, flip angle 8°, inter-shot interval 3000ms, imaging time 11.9mins). At 3T, a 2D multi-slice DIR sequence was used (256x192x152mm FOV, 1x1x2 mm voxels, TE = 100ms, TR = 11s, inversion delays of 3400 and 325ms, TSE factor 26, acquired in 11.5 minutes). In addition a 2D multi-slice FLAIR image (256x204x140mm FOV, 1 x 1 x 2.5 mm<sup>3</sup> voxel size, turbo spin echo factor 27, 120° refocusing pulse, TE = 125ms, TR = 11s, TI = 2800ms, imaging time 6mins) was acquired at 3T.

All images were registered to the same space using FLIRT<sup>5,6</sup>. 3T DIR images were used to identify focal signal abnormality involving the cortex. Lesion identification using 3T FLAIR images and the 7T MPRAGE images was subsequently performed. The DIR, FLAIR and MPRAGE images were viewed side by side. Cortical lesions identified in DIR images were defined as being (1) identified prospectively on FLAIR, (2) identified retrospectively on FLAIR, or (3) not visible on FLAIR. Further, each lesion was then characterised as being (1) identified retrospectively on MPRAGE or (2) not visible on MPRAGE. The spatial characteristics of identified lesions were also considered and lesions were defined as intracortical, juxtacortical, or spread across the GM/WM boundary.

**Results and discussion:** Figure 1 shows 7T MPRAGE and 3T DIR images of an MS patient. This figure highlights how a hyperintense blood vessel, clear in the MPRAGE image, could be misinterpreted as cortical abnormality in the DIR image. This is a consequence of the relatively low spatial resolution of 3T DIR, and supports previous work showing the susceptibility of DIR to artifact. In the 11 patients scanned, 16 signal abnormalities classified as intracortical lesions using DIR were found to correspond to an adjacent extracortical vessel on 7T MPRAGE.

A total of 120 cortical signal abnormalities were detected on the 3T DIR images. In contrast 3T FLAIR images detected 84 cortical lesions and 7T MPRAGE detected 97 cortical lesions. Comparison between the image types revealed that 68% and 65% of the cortical lesions viewed on DIR could be identified on 3T FLAIR and 7T MPRAGE images respectively. However, the 7T MPRAGE proved considerably more useful in determining the precise anatomical location of the lesions identified. Of the 63 lesions defined as purely intracortical on DIR, 8 were found to be juxtacortical (pure WM) and 11 were found to be mixed GM/WM lesions on 7T MPRAGE.

Figure 2 shows two examples of lesions that were seen in DIR, FLAIR and MPRAGE images. In DIR and FLAIR images it was difficult to state with certainty the spatial characteristics of the lesion. However, using the 7T MPRAGE this was achievable, facilitated by the increased spatial resolution available.

**Conclusion:** Imaging cortical lesions in MS represents a challenge for MRI. We echo previous findings<sup>2,4</sup> that although DIR sequences demonstrate good sensitivity to GM lesions, this sequence is prone to artifact and thus results may be unreliable. We have also shown that a significant improvement in reliability of detection can be achieved by combining DIR with MPRAGE at ultra high field and FLAIR. The fact that GM lesions can be identified in the same location using different sequences on different scanners is compelling. Importantly 7T not only validates the presence of lesions, but the excellent spatial resolution available at this field strength also enables accurate measurement of the spatial characteristics of these lesions. We believe further work should now use the techniques described to assess the clinical significance of these cortical lesions.

**References:** 1) Geurts et al. *AJNR Am J Neuroradiol.* Mar 2005;26(3):572-577. 2) Geurts et al. *Radiology.* Jul 2005;236(1):254-260. 3) Calabrese et al. *Arch Neurol.* Oct 2007;64(10):1416-1422. 4) Nelson F, *AJNR Am J Neuroradiol.* Oct 2007;28(9):1645-1649. 5) [www.fmrib.ox.ac.uk/fsl/](http://www.fmrib.ox.ac.uk/fsl/) 6) Jenkinson et al, *NeuroImage*, 17, 825-841, 2002

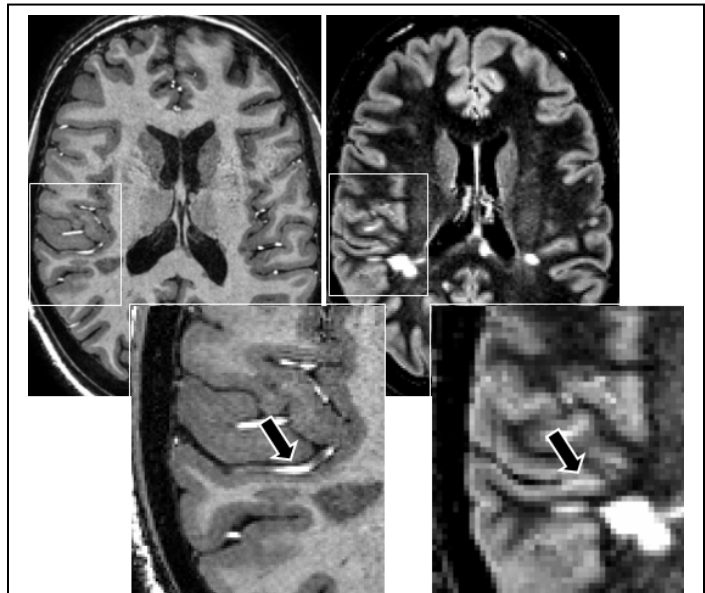


Fig. 1: 7T MPRAGE (left) and 3T DIR (right) images acquired in the same subject. Notice that a hyperintense blood vessel, clear in the MPRAGE could be misinterpreted as a cortical abnormality in the DIR.

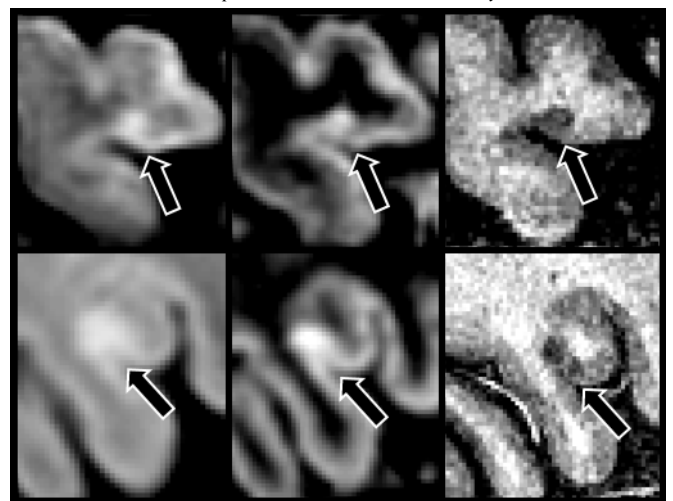


Fig. 2: Two cortical lesions in subject 1 (top) and subject 2 (bottom). Lesions can be observed in FLAIR (left) DIR (centre) and MPRAGE (right)