High resolution Magnetization Transfer Imaging at 7T : detection of cortical lesions in MS patient

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Purpose:
In Multiple Sclerosis there is poor correlation between clinical disability and the WM lesions that are clearly detected by MRI. The high frequency of cortical demyelination in progressive MS and intra-cortical (IC) lesions in pathology suggests that cortical demyelination may account for some chronic features of MS. However cortical lesions have proved difficult to detect with MRI. Magnetization transfer (MT) is sensitive to white matter demyelination in Multiple Sclerosis (MS), but high field MT measurements are required to provide adequate sensitivity and spatial resolution across the cortex. MT is difficult to implement at 7T because of SAR limits, but it has previously been measured using a pulsed saturation train followed by a turbo-field echo readout (MT-TFE). Here we have adapted this sequence to provide high spatial resolution MT images and have used these to study MS lesions at 7T and focused on MS patients with possible grey matter lesions.

Method:
MS patients (N=3) were scanned in accordance with approval from the local ethics committee. Scanning was carried out using Philips Achieva scanner at 7T. The high resolution MT-RAGE sequence was acquired at two different resolutions. Each one required the acquisition of two images: MT_{sat} and MT_{noSat}. The first (MT_{sat}) applied a train of 20 off-resonance pulses (13.5 µT Gaussian-windowed, sinc pulses with a bandwidth of 200 Hz and off-resonance by 1.1 kHz, with 50 ms between each pulse), followed by a Turbo-Field echo (TFE) readout (flip angle=8°, centre out k-space sampling, FOV 200x200x20mm, and either TR/TE=19/11ms or TR/TE=25/15ms, giving resolutions of $0.5x0.5x0,5mm^3$ (isotropic) or $0.35x0.35x1mm^3$ (high res. in plane), with total imaging time of 9min or 4min50s,). The shot to shot interval (SSi) was 10 s. The second (MT_{noSat}) image was a reference image acquired as the TFE sequence, with no off-resonance saturation pulses applied. High resolution MT ratio images were calculated by computing $(MT_{noSat}-MT_{sat})/MT_{noSat}$ on a pixel by pixel basis. Additionally an MPRAGE image (resolution of 0.5mm isotropic) and T_2star weighted images known to be sensitive to grey matter lesions were also acquired (3D gradient echo images with the same resolution as the MT-RAGE).

Results:
Different type of lesions could be seen, both in the MT_{sat} and MT_{noSat} images. The detection of intra-cortical lesions, as well as mixed white matter/ grey matter lesions was possible on the MT images, as well as on the MTR maps. However a better detection is possible if both images are analysed together (the MTR map providing contrast and the MPRAGE or base MT-TFE images providing delineation). Using the classification system by Bö et al [3], detection of lesions of class I, II and IV could be achieved in vivo on the MT images. The lesions had very high contrast on the MTR maps (fig 1D) despite the fact that the contrast to noise ratio of the MTR maps is low due to the ratio calculation. Quantitative comparison of the contrast to noise ratio (CNR) of the isotropic and high in-plane resolution images was computed using the propagation of errors from the raw MT images [4]. The isotropic resolution images gave slightly better white-grey matter CNR than the high-res ones but with larger inter-subject standard deviation (0.16±0.10 versus 0.14±0.07). However lesions could be detected more easily in the high-res images due to a higher CNR between the grey matter and the lesions (0.12±0.07 compared to 0.08±0.06), probably due to reduced partial volume effects.

Discussion:
As far as we are aware this is the first report of MTR changes in cortical lesions. The MT maps provide high contrast to the cortical lesions and offer the possibility of monitoring changes in the cortex quantitatively. High resolution MTR maps will also allow smaller WM lesions to be investigated. Ultrahigh field 7T provides improved sensitivity allowing increased spatial resolution and also sensitivity to grey matter myelin. This sequence forms part of a protocol used in an ongoing study of MS patients at 7T, and the appearance of cortical layers on high resolution MTR scans from these patients is now being investigated.

[1]: Mougin, O, et al, Neuroimage, 2010 : 49: 272-281 **[2]:** Deichmann, R., et al., Neuroimage, 2000; 12: 112-127. **[3]** Bö, L et al, Mult Scler, 2003 : 9 : 323-331.
[4] Cercignani et al, NeuroImage 31, 181-186, 2006.
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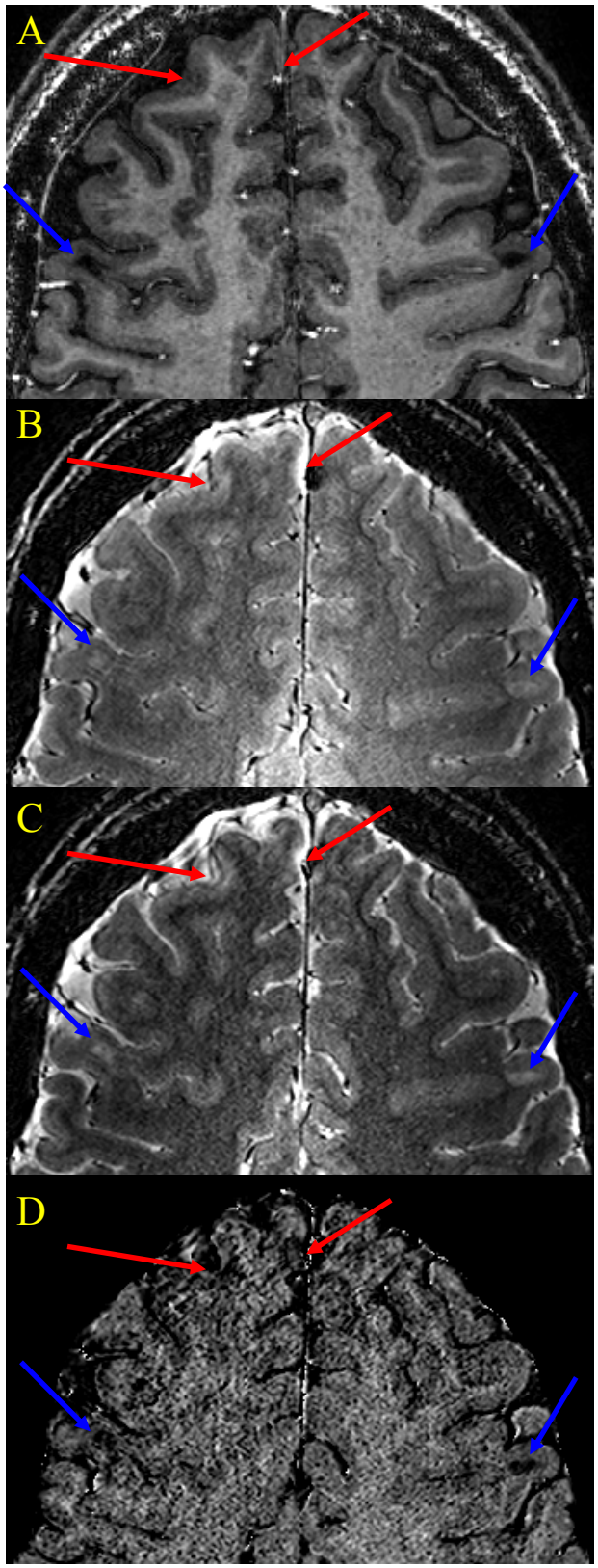

Fig. 1: The MP-RAGE image (A) shown some abnormalities on the cortex of the patient, but not easily detectable. The MT-RAGE images with MT_{noSat} (B) and MT_{sat} (C) versions, with the corresponding MTR map (D). Area of the cortex which appears hyper-intense on both images are likely to be intra-cortical lesions. Red arrows shows cortical lesions, while blue arrow show mixed WM/GM lesions.