MRI of Multiple Sclerosis with High Contrast Susceptibility-Weighting and Extreme Resolution T2-Weighting

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Introduction - Multiple sclerosis (MS) is an autoimmune disease of unknown origin. From pathology, it has been recognized that MS lesions are centred on veins and there is increasing evidence that local iron overload may be the initial signal of the inflammatory chain in MS (1). It may be possible to visualize this iron overload in phase images with highly sensitive susceptibility-weighted (SW) imaging, particularly at high magnetic fields that allow high spatial resolution with reduced echo times to attain contrast sensitivity (2). However, SW imaging alone does not provide a complete picture of MS and should be combined with more standard spin echo T2-weighted imaging. These approaches at low field typically use spatial resolution ~5 mm^3, which may limit the visibility of small lesions. If not constrained by patient heating, higher magnetic fields can vastly increase this spatial resolution (3), but must also maintain high efficiency to provide adequate slice coverage in clinical scan times. By increasing the magnetic field to 4.7 T, we are able to provide increased SNR and SW contrast over lower field clinical systems, while maintaining robust T2-weighted fast spin echo imaging (4), in order to study MS at a new level of spatial resolution and contrast.

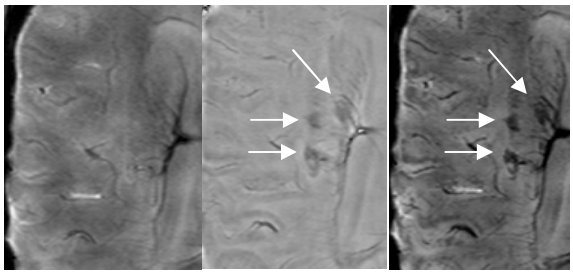
Methods - Six patients diagnosed with MS were recruited from the neurology clinic. Each patient received a 4.7 T MRI brain exam using 2D T2-weighted fast spin echo and 3D susceptibility-weighted imaging. A further 1.5 T standard clinical exam was performed without contrast agent. The resultant 4.7 T images were reviewed by a team of three radiologists to determine lesion conspicuity in the magnitude T2-weighted, T2* -weighted, as well as phase and SW images. Quantitative SNR and CNR measurements were also performed. The imaging parameters at 4.7 T follow.

Extreme resolution fast spin echo: 1.75 mm slice thickness, 22 slices, TE/TR 44/6250 ms, flip angle 90° excitation followed by 160º refocusing pulses, 8 echoes, in-plane matrix 700 x 512, FOV 20 x 17 cm yielding 0.19 mm^3 true voxel volumes.

Susceptibility-weighted imaging: TE/TR 20/70ms, 20º excitation, 22 slices per slab, 3 mm thickness, 512 x 256 in-plane matrix, 6.6 minutes per slab. Processed into 3 images: magnitude, unwrapped and filtered phase, and thresholded phase multiplied 4-fold into magnitude to create SW image (2).

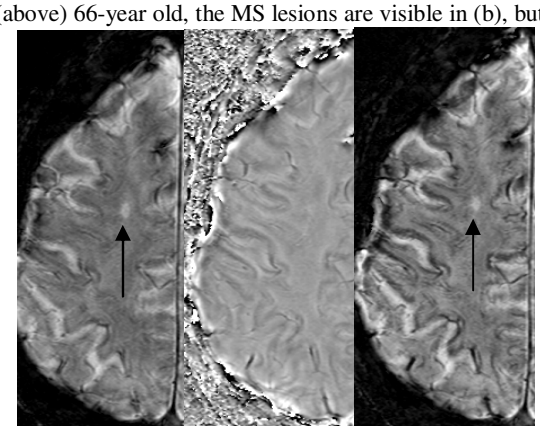
Results – Images from 4.7 T are shown from three separate MS patients in Figs 1-3. In Fig 1, the MS lesions (arrows) are visible on the phase image but not on the standard magnitude. In Fig. 2, the marked lesion is not visible in the phase image. For most patients, lesions visible on T2-weighted imaging were not visible on the phase images. In Fig. 3, MS lesions are illustrated with extreme spatial resolution FSE using only 0.19 mm^3 voxels approximately twenty times smaller voxel size than standard clinical MS images. The higher field provided improved lesion conspicuity especially for small lesions, such as the corpus callosum lesion in Fig. 3, that was not visible with standard clinical T2-weighted imaging at 1.5T.

Conclusions – Imaging at 4.7 T provided increased SNR and SW contrast, enabling exquisite SW contrast and much higher spatial resolution in FSE, while maintaining a robust multislice technique. Further field increases above 4.7 T may limit the effectiveness of multislice FSE due to SAR limitations, and suffer from increased signal losses at air-tissue interfaces in SW imaging. The vast majority of lesions that were visible on T2-weighted FSE were not visible on the SWI phase images. Visualisation on the phase image may provide a new contrast mechanism similar to gadolinium-enhancement for active MS lesions. Future studies will investigate the link between gadolinium enhancement and the phase SW images.



(a) magnitude (b) phase (c) SW image

Fig 1 (above) 66-year old, the MS lesions are visible in (b), but not in (a).



(a) magnitude (b) phase (c) SW image

Fig 2 59-year old, the MS lesions are visible in (a), but not in (b).

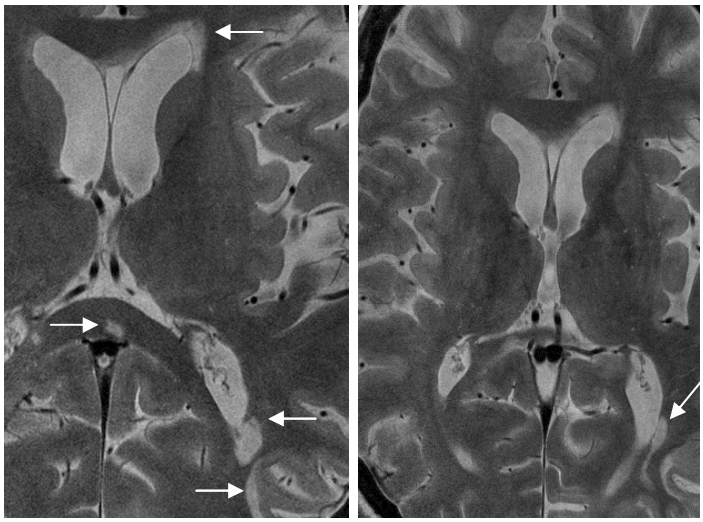


Fig. 3 63 year old MS patient showing multiple lesions using 0.19 mm^3 voxels for T2-weighted fast spin echo at 4.7 T. Arrows show select lesions including cortical and periventricular lesions as well as a tiny lesion in the corpus callosum (left image).

References

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