Comparing 3T and 7T in the detection of small parenchymal blood vessels in MS lesions

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Introduction: Post mortem studies[1] of white matter (WM) demyelination in multiple sclerosis (MS) suggest that WM lesions are associated with small parenchymal blood vessels, supporting a hypothesis that formation of an MS lesion depends on the entry of inflammatory cells from the systemic circulation into brain parenchyma. However, the notion that every MS plaque shares this common mechanism has been challenged. The ability to image WM lesion and venous distribution using MRI *in vivo* could prove a useful tool to gain a better understanding of WM lesion formation. Imaging of MS lesions and parenchymal blood vessels has been attempted previously using MR angiography and T_2 weighted images[2] but this technique necessarily relies on mm accuracy in image co-registration. Previously we have taken advantage of the increased susceptibility effects at ultra high field to demonstrate that T_2*-weighted images allow visualization of MS lesions and blood vessels in a single scan without the need for contrast agent[3]. In view of the low availability of ultra high field scanners, here we investigate whether it is possible to generate similar contrast using the more accessible 3T field strength.

Methods: Seven subjects with relapsing-remitting MS were recruited along with seven healthy volunteers. All subjects gave informed consent and the study was approved by 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 3D gradient echo acquisition with T_2* weighting. 200 contiguous transverse slices were acquired covering the brain in 4 stacks. (192x164x100mm FOV, 0.5mm isotropic voxels, TE = 20ms, TR = 150ms, flip angle 14°, SENSE factor 2, EPI factor 3, imaging time 8.8mins.) A T_1-weighted MP-RAGE image (192x164x100mm FOV, 0.5mm isotropic voxels, TE = 6.5ms, TR = 14ms, TI = 1033ms, flip angle 8°, inter-shot interval 3000ms, imaging time 11.9mins) was also acquired at 7T. At 3T, a T_2* weighted sequence giving whole brain coverage using 4 stacks, each comprising 32 transverse slices was used. (192x164x102.4mm FOV, 0.8mm isotropic voxels, TE = 20ms, TR = 150ms, flip angle = 14°, SENSE factor 2, EPI factor 3, imaging time 7.2 minutes.) A 2D multislice FLAIR image (256x204x140mm FOV, 1 x 1 x 2.5 mm^3 voxel size, turbo spin echo factor 27, 120° refocusing pulse, TE = 125ms, TR = 11s, TI = 2800ms, imaging time 6mins) was also acquired at 3T.

All images were registered to the same space using FLIRT in FSL[4,5]. Lesions were initially identified using the 3T FLAIR image. An observer then determined whether each 3T FLAIR lesion was visible in T_2* images acquired at 3T and 7T. For lesions considered to be visible in T_2* images, the presence or absence of a blood vessel was noted. Vessels were hypointense in T_2*-weighted images and were only counted if they (i) could be visualised in at least 2 perpendicular planes, (ii) appeared extended in at least one plane and (iii) were completely surrounded by the lesion in at least one plane (to avoid the inclusion of adjacent rather than central vessels). Differences between the detection frequency of lesions and central vessels on 3T and 7T T_2* scans were analysed using unpaired t-tests.

Results: Both 3T and 7T T_2* imaging sequences were capable of detecting both white matter MS lesions and large blood vessels. Figure 1A shows a typical 7T T_2* image and figure 1B shows the equivalent 3T image. Notice that although a central vessel is observable at 3T, it is much clearer on the 7T image. Figure 2 A and B shows a small subcortical lesion at 7T and 3T respectively. Magnified versions of the lesion are inset. Notice that a central vessel within the lesion is apparent on the 7T image but is not clear in the 3T image.

FLAIR images at 3T demonstrated a total of 358 lesions in 7 patients (mean 51 lesions per patient, range 24-92). The 3T T_2* sequence detected 89% of those FLAIR lesions. The 7T T2* sequence detected 94% or those lesions. A central blood vessel could be identified in 141 lesions using 3T T_2* (45% of visible lesions, range 18-86% per patient) whereas at 7T, 292 lesions appeared to exhibit a central vessel (87% of visible lesions, range 75-94% per patient).

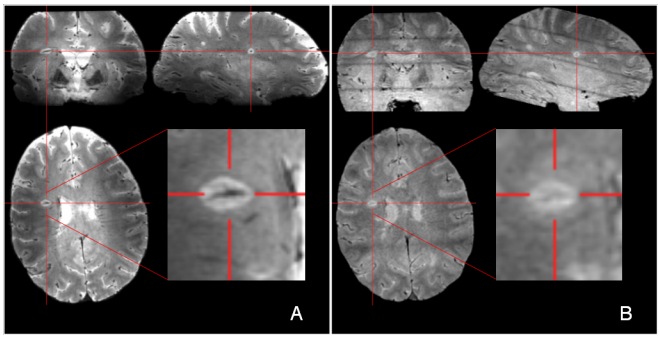

Fig. 1: A white matter lesion with a large central blood vessel imaged at A) 7T and B) 3T.

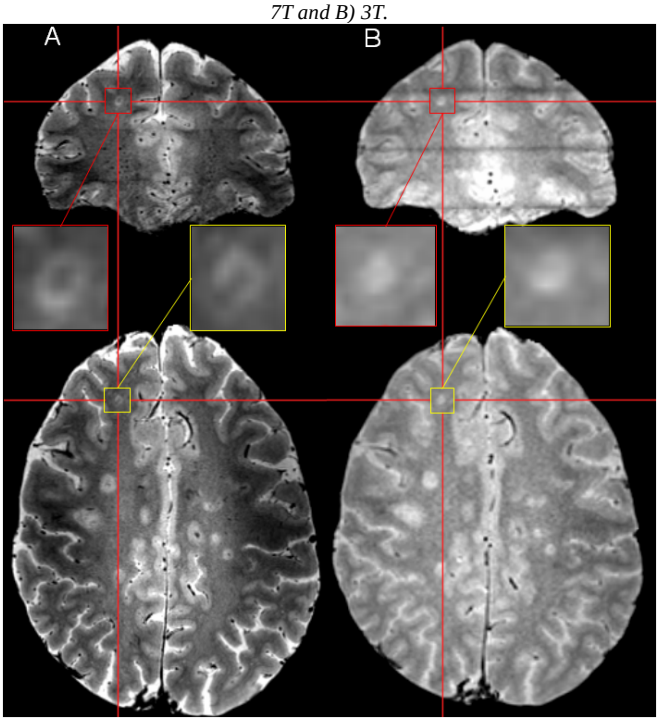

Fig. 2: A smaller MS WM lesion imaged at A) 7T and B) 3T. Notice that a central vessel is observable at 7T but not at 3T

Discussion: Both 3T and 7T T_2* sequences exhibit sensitivity to WM lesions. However, using the sequence parameters described we found that the 7T sequence was significantly better at detecting intra-lesional vessels than 3T. This supports the hypothesis that 7T imaging is advantageous in demonstrating detailed structural anatomy. The echo times and image resolution used for 3T and 7T T_2* sequences were selected to optimise contrast, SNR and decrease imaging time. At 7T, enhanced susceptibility effects around blood vessels means that relatively short echo times can be used to generate sufficient T_2* contrast to see the vessel, while maintaining a high SNR, excellent spatial resolution and a clinically acceptable acquisition time. The combination of the lower spatial resolution, lower SNR and decreased sensitivity to susceptibility effects are likely to contribute to the limited ability to detect vessels using 3T imaging. In principle, at 3T a longer echo time might yield equivalent contrast between vessels and surrounding tissue, however extending the echo time would decrease the SNR, meaning that spatial resolution must be sacrificed.

Conclusion: This work supports T_2*-weighted imaging at ultra-high field as a means for investigating the relationship between WM lesion distribution and the spatial distribution of parenchymal vessels. Such techniques could prove clinically useful if it transpires that features of lesion appearance relate to patterns of clinical phenotype and treatment response.

References: 1) Lucchinetti *et al*. Ann Neurol, 47, 707-717, 2000. 2) Kozinska *et al*, NeuroImage, 22, 1671-1678, 2004. 3) Tallantyre et al, Neurology, 70, 2076-2078, 2008. 4) www.fmrib.ox.ac.uk/fsl/ 5) Jenkinson et al, NeuroImage, 17, 825-841, 2002