Diminished Venous Vasculature on Susceptibility Weighted Imaging Venography in Multiple Sclerosis

Y. Ge[1], E. O. Osa[1], M. Law[1], J. Xu[1], J. H. Jensen[1], E. M. Haacke[2], and R. I. Grossman[1]

[1]Department of Radiology, New York University School of Medicine, New York City, NY, United States, [2]MRI institute for Biomedical Research, Detroit, Michigan, United States

Introduction: Susceptibility-weighted imaging (SWI) is a sequence that enhances MRI contrast by exploiting susceptibility differences between tissues [1]. SWI uses a fully flow-compensated, 3D, RF spoiled, high resolution, gradient echo scan with the application of filtered phase images to enhance contrast via susceptibility differences between tissues. It was originally designed to better visualize veins [2], which generate susceptibility contrast due to high levels of deoxyhemoglobin that decreases signal in the venous blood as a result of increased local field inhomogeneity and spin dephasing [3]. The perivenous relationship of multiple sclerosis (MS) lesions has been demonstrated by both postmortem [4] and *in vivo* studies [5], which may cause venous occlusive pathology [6]. In this study, the visibility of the venous vasculature between patients with MS and normal controls was compared using high resolution SWI venography.

Methods: Eighteen patients with clinically definite MS were studied at 3T (Trio, Siemens Medical Solutions). The mean age was 44.8 yrs and the mean duration of the disease at the time MRI was performed was 5.6 yrs (range, 1.3-14.9 yrs). Also 15 healthy volunteers (9 women, 5 men; mean age: 39 years range from 23 to 55 years) served as controls. SWI was performed using a 3D high resolution gradient echo scan with full flow compensation (TR/TE/flip angle: 50ms/20ms/25^{o}; matrix: 512x512; voxel size: 0.43x0.43x2mm^{3}). SWI minimal intensity projection (mIP) images over 4 slices (8mm thick) were created using both magnitude and phase images to illustrate venous structures. The algorithm to enhance the contrast involves applying a high-pass filter [7] and phase multiplication [1]. We counted the number of veins for each subject in the periventricular white matter region at the level just below the centrum semiovale, which is the most common place that MS lesions occur. We also correlated the number of veins counted with the lesion load in these patients.

Results: On SWI mIP images, veins, which are not visible on conventional MRI, appear as dark linear structures in contrast to bright white matter background. We found a significant difference of the number of veins counted in the periventricular region ($p = 0.001$) between patients (mean/SD: 11.3 ± 9.2) and controls (mean/SD: 28.8 ± 8.1), indicating remarkably diminished venous structures visualized on SWI venography in MS patients. The number of veins had a negative correlation between the number of lesions in patients with MS ($r= -0.56$, $p=0.02$). *Figure 1* demonstrates conventional T2-weighted and SWI mIP images in the periventricular level in one normal subject (A) and two MS patients (B, C). We can see the number of veins visualized on SWI was reduced in patients compared with controls and more significantly in patients with more lesions.

Discussion: SWI offers the opportunity for noninvasive assessment of venous vascular architecture and possible pathophysiology. We interpret our findings of decreased visibility of veins in periventricular white matter in MS patients to be a result of diffuse microvascular pathology due to the direct venous vascular injury or occlusion by lesions [6]. This is consistent with the previous perfusion MRI data showing significant decrease of blood perfusion in the periventricular region in MS [8]. Our finding of an inverse relationship between the number of detected veins on SWI venogram and lesion load also supports our interpretation, indicating the vascular pathogenesis of MS lesion. The diminished venous vasculature in MS may be also due to reduced oxygen utilization in the chronic diseased tissues that leads to decreased level of deoxyhemoglobin in veins, which can be potentially differentiated by future studies of vasomotor reactivity using acetazolamide or caffeine [9]. In summary, direct visualization of venous architecture on high resolution SWI may provide a valuable tool for assessment of microvascular abnormalities in MS.

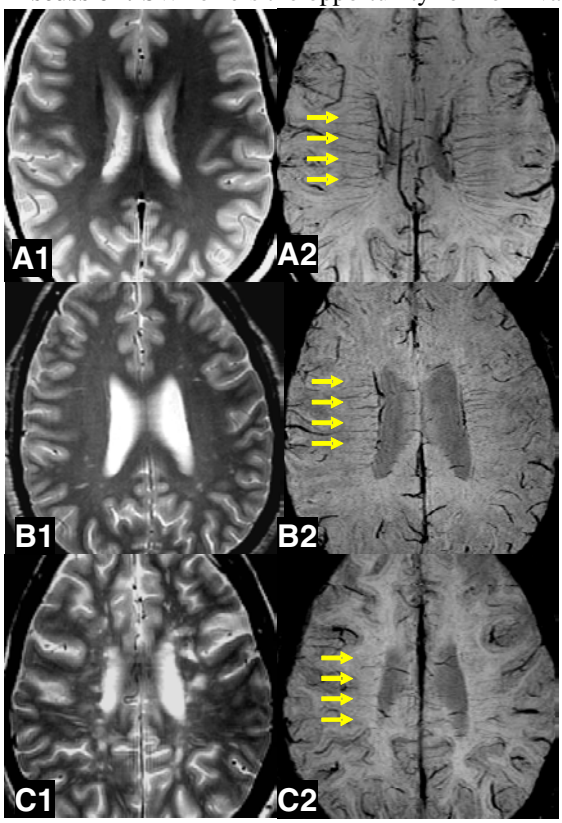

Fig 1. *Conventional T2-weighted (A1, B1, C1) and SWI mIP images (A2, B2, C2) at the periventricular level (8mm thick) in a normal control (A) and two MS patients (B, C) demonstrate a significantly reduced number of veins in patients compared to controls. MS patient with more lesions (C) has less venous architectures depicted on SWI mIP image than MS patient with fewer lesions (B).*

References

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