# Quantitative Venous Vasculature Assessment on Susceptibility-Weighted Imaging Reflects Presence of Severe Chronic Venous Insufficiency in the Brain Parenchyma of Multiple Sclerosis Patients. A Case-Control Study

**G. U. Poloni[1], P. Zamboni[2], E. Haacke[3], S. Bastianello[4], M. G. Dwyer[1], N. Bergsland[5], C. V. Schirda[1], D. Wack[1], C. R. Magnano[1], B. Weinstock-Guttman[6], F. Salvi[2], D. Hojnacki[6], and R. Zivadinov[1]**

[1]University at Buffalo, Buffalo Neuroimaging Analysis Center, Buffalo, NY, United States, [2]University of Ferrera- Bellaria Neurosciences, Vascular Diseases Center, Ferrera, Italy, [3]Radiology, Wayne State University, Detroit, MI, United States, [4]Institu Neurologico Casimiro Mondino, Neuroradiology Unit, Pavia, Italy, [5]University at Buffalo, Buffalo Neuroimaging Analysis Center, Buffalo, United States, [6]University at Buffalo, The Jacobs Neurological Institute, Buffalo, NY, United States

**Objective:** To develop an objective method for quantifying venous vasculature in brain parenchyma on susceptibility-weighted imaging (SWI)[1] and to apply this technique in multiple sclerosis (MS) patients and in healthy controls (HC) in a case-control study.[2,3]

**Background:** SWI is a MRI application that can directly image cerebral veins through the use of phase information to enhance local susceptibility or T2* contrast,[3,4,5] providing a unique means for quantitatively assessing the diminished visibility of cerebral venous vasculature in MS, reported in literature.[3,2]

**Material and Methods:** Sixty-two (62) MS patients (44 relapsing-remitting and 18 secondary-progressive, $43.5 \pm 11.8$ yrs) and 33 age- and sex-matched HC were imaged on a 3T GE scanner using pre-contrast SWI. A subset of MS patients (50) and HC (7) obtained SWI post-gadolinium contrast sequence (0.1 mMol/Kg Gd-DTPA with 10 min delay). An in-house developed segmentation algorithm, based on a 3D multi-scale line filter,[5] was applied for vein segmentation (Fig. 1-a). Absolute volumetric measurements for total vein vasculature were performed in milliliters (ml) and the relative venous intracranial fraction (VIF) was obtained to correct for head size and amount of brain atrophy. The size of individual veins was measured in mm and 4 groups were created according to their diameter (D): (<0.3mm, 0.3-0.6mm, 0.6-0.9mm and >0.9 mm). Voxel brain average distance-from-vein maps were also calculated with higher distance indicating lower vein density (Fig. 1-b).

**Results:** A significantly lower absolute venous volume was detected in MS patients compared to HC, both in pre-contrast (67.5 vs. 82.7ml, -18.4%, $p<0.001$) and post-contrast (70.4 vs. 87.1ml, -19.3%, $p<0.011$) images. The VIF was significantly lower in MS patients ($p<0.001$). The highest D-based difference was found for the smallest veins (<0.3 mm), both on pre- ($p<0.001$) and post-contrast ($p<0.018$) images. The distance-from-veins was also significantly higher in MS patients ($p<0.001$) in pre-contrast scans (Tab. 1).

**Discussion and Conclusions:** We developed and validated a quantitative vein segmentation method that showed altered visibility of venous vasculature on SWI pre- and post-contrast images in MS patients. These findings demonstrate that venous drainage of brain parenchyma is severely compromised in MS patients.

| | Multiple Sclerosis | Healthy Controls | % difference | p value |
|---|---|---|---|---|
| **Total venous volume pre-GAD** | $(67.5 \pm 19.8)$ml | $(82.7 \pm 17.1)$ml | -18.4% | **<.0001** |
| **Venous volume with diameter <0.3mm pre-GAD** | $(45.3 \pm 10.7)$ml | $(53.3 \pm 10.1)$ml | -15.0% | **.001** |
| **VIF pre-GAD** | $0.048 \pm 0.013$ | $0.058 \pm 0.011$ | -17.2% | **.001** |
| **VIF of venous volume with diameter <0.3mm pre-GAD** | $0.032 \pm 0.007$ | $0.037 \pm 0.006$ | -13.5% | **.003** |
| **Average distance from veins pre-GAD** | $(1.20 \pm 0.23)$mm | $(1.04 \pm 0.13)$mm | +15.4% | **<.0001** |
| **Total venous volume post-GAD** | $(70.3 \pm 19.0)$ml | $(87.1 \pm 18.0)$ml | -19.3% | **.011** |
| **Venous volume with diameter <0.3mm post-GAD** | $(49.0 \pm 10.3)$ml | $(58.3 \pm 0.76)$ml | -16.0% | **.018** |
| **VIF post-GAD** | $0.049 \pm 0.015$ | $0.061 \pm 0.009$ | -19.7% | **.039** |
| **VIF of venous volume with diameter <0.3mm post-GAD ICV** | $0.034 \pm 0.009$ | $0.041 \pm 0.0056$ | -17.0% | **.046** |
| **Average distance from veins post-GAD** | $(1.17 \pm 0.34)$mm | $(0.94 \pm 0.16)$mm | 24.5% | .104 |

**Tab 1:** Quantitative venous vasculature differences between multiple sclerosis patients and normal controls. VIF-venous intracranial fraction
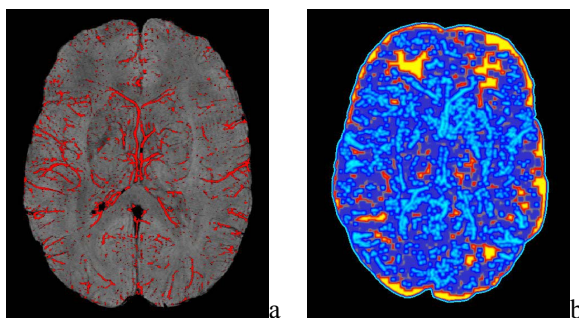


**Fig. 1** Sample vein mask overlaid on the corresponding SWI image (a) and explanatory image (b) overlaying the distance-from-vein map on the corresponding vein and SWI map: the color coding expresses the distance-from-a-vein.

**Bibliography**

1) Haacke, et al. Magn Reson Med 2004; 52: 612-618 ; 2) Ge, Y., et al. J Magn Reson Imaging 2009; 29: 1190-1194; 3) Tan, I. L., et al. Am J Neuroradiol 2000; 21: 1039-1042; 4) Fujii, S., et al. Am J Neuroradiol 2009 Sep 3 [Epub ahead of print]; 5) Chapman, B. E., Parker, D. L. Med Image Anal 2005; 9: 191-208