Comparison of Susceptibility-Weighted-Imaging determined vessel diameters to histological measures

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Introduction:

Susceptibility-Weighted-Imaging (SWI) allows high resolution imaging of the venous system which is based on SWI phase images. However, phase images reflect the magnetic susceptibility of tissues only indirectly, since a phase image is the convolution of the susceptibility-carrying volumes with the typical pattern of a magnetic dipole [1] which additionally increases the size of paramagnetic structures. An advantage of that contrast mechanism is that it allows the visualization of paramagnetic structures which are much smaller than the actual pixel resolution [2]. The purpose of this study was to determine the relation between apparent SWI vessel sizes and real vessel diameters measured on histological tissue slides. Two in-vitro SWI acquisitions were performed on brain tissue samples of one healthy and one multiple sclerosis (MS) brain. Furthermore we compared the SWI enlargement factor in healthy brain tissue to the MS brain.

Materials and Methods:

Brain tissue: After autopsy, both brain specimens were fixed in 4% neutral-buffered paraformaldehyde (PFA) solution for 6 months. After fixation, brains were cut into blocks (~6x6x1cm), which were placed in a homemade cylindrical plastic container (diameter 70 mm) filled with perfluoropolyether (Galden SV 80™, Solvay Solexis, Milan, Italy) to reduce background signal and artifacts from air bubbles.

Data acquisition: SWI was performed with a three-dimensional gradient-echo sequence with a TE of 15 ms on a 7T system (Siemens Erlangen, Germany). Other sequence parameters were: TR = 24 ms, image-matrix = 576x576 pixel, slices = 144, acquisition time = 33.18 min, averages=6, resolution = 0.14x0.14x0.35 mm using a 72mm volume coil (RAPID Biomedical, Würzburg, Germany).

Histology: Following SWI, tissue blocks were dehydrated, grouted in paraffin and cut in 5µm thick sections closely parallel to MRI slices. Sections were stained for iron (DAB-enhanced Turnbull blue method) [3] and hematoxylin & eosin (H&E). Intraluminal vessel diameters were measured on H&E-stained sections with a Nikon DS-Fi1™ digital camera mounted on a Reichert Polyvar 2™ microscope using the Nikon NIS Elements™ software version 3.10. SWI vessel diameters were quantified using ImageJ version 1.43r.

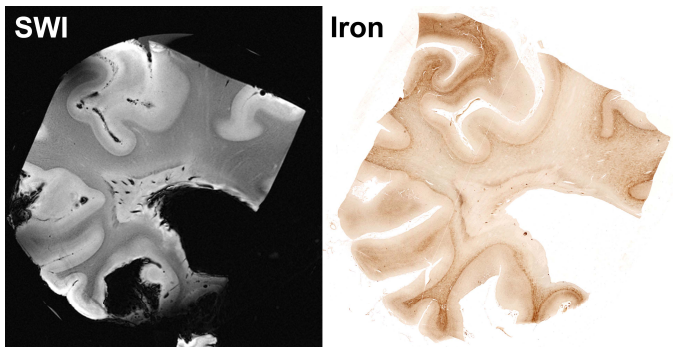

Figure 1: SWI (left) and an iron staining (right) of a representative slice through the MS tissue block.

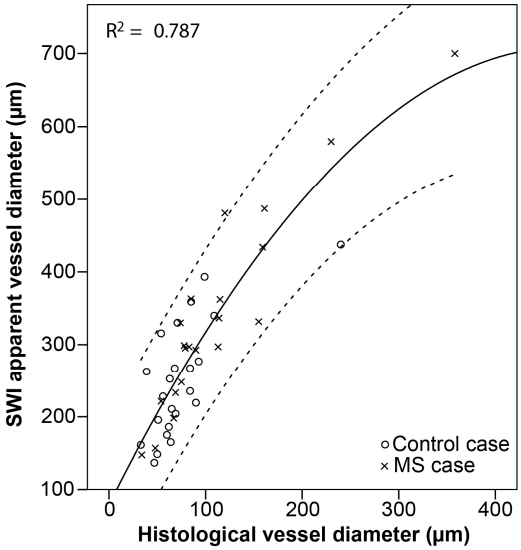

Figure 2: SWI vessel diameters versus histologically measured vessel diameters. The solid line represents the quadratic regression and the dashed lines the 95% confidence interval.

Results:

The average vessel diameter within the healthy brain was 75.5 µm (Standard Deviation (SD) 39.2 µm) in histology and 250.7 µm (SD 79.1 µm) on the SWI data. Both measures correlated significantly ($r_{Pearson}$ = 0.7; $p < 0.01$). The average vessel size within the MS brain was 112.4 µm (SD 70.9 µm) on histological and 337.7 µm (SD 133.2 µm) on SWI data, also correlating significantly ($r_{Pearson}$ = 0.919; $p < 0.01$). The average ratio of the SWI vessel size and the histological vessel size for vessels with a histological diameter < 100 µm was 3.720 for the control brain and 3.706 for the MS brain. An example for an SWI image and the corresponding iron staining is displayed in Figure 1. The MRI diameters are plotted against histological diameters in Figure 2. As can be seen in Figure 2, the SWI enlargement factor is higher for smaller vessels and shrinks for larger vessels.

Discussion and Conclusion:

These data indicate an SWI enlargement factor of about 3.7 for vessels with a histological diameter below 100 µm independently from disease status. The SWI enlargement factor decreases for larger vessels. As the anatomical positions of the individual vessels were not considered for analysis, the conclusion that vessels in MS lesions are larger compared to healthy brain tissue is not valid.

References:

1) Pathak et al. NeuroImage 2008;40:1130-1143 ; 2) Reichenbach et al. Radiology. 1997 Jul;204(1):272-7.
3) Meguro et al. Archives of histology and cytology 2007;70(1):1-19