Iron Quantification in the Putamen using Susceptibility Maps

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Introduction: Susceptibility Weighted Imaging (SWI) uses phase to enhance imaging contrast in final SW images. Furthermore, SWI phase images have been used for iron quantification, vascular imaging and detection of iron deposits in the brain. Conventional SWI data processing relies on the phase information for iron quantification and vascular imaging, which is dependent on the shape, size and orientation of the structure. A new imaging processing method called susceptibility weighted imaging and mapping (SWIM) has been developed recently to address these issues (1). Using SWIM, high resolution isotropic or approximately isotropic data can be used to generate Susceptibility Map (SM) of whole brain including the small veins independent of the size and the orientation of the vessels (1). In this study, we used SWIM to quantify iron content in the putamen in healthy human subjects in a wide age range from 21 to 69 years old.

Method: High resolution (0.5x0.5x1mm^3) SWI were collected in 15 subjects of young, middle age and older adults (5 in each group, young = 24.2 ± 3.8, mid = 45.4 ± 3.5, old = 65.2 ± 3.0 yrs). All MRI scans were performed on Philips 3.0 Tesla MR systems (Philips Medical Systems, Best, The Netherlands) at the Advance Imaging Research Center at University of Texas Southwestern Medical Center. SWI data was acquired using a flow compensated gradient echo sequence, with phase reconstruction ON, using following parameters: 3T; GRE; Axial images with FOV 256x256mm, Matrix size 512x512, slice thickness 1mm. TR=30 ms and TE=9 and 20ms, FA 15^0, SENSE factor 2. SWIM processing used a regularized inverse filter to the Fourier transform of high-pass filtered phase images to reconstruct the susceptibility distribution. The regularization parameter "a" of the inverse filter was restricted to have a minimum absolute value to prevent the filter from ill defined which may lead to an increase in signal noise level near singularities. In this study, a threshold value of 0.1 was used for SWIM processing. Major steps involved in SWIM processing are as follow: **i)** Filtering phase images: Phase images were High-pass filtered with 32x32 filter size to remove low spatial frequency. **ii)** K-space zero filling: Initial phase images were zero filled to a larger matrix size to reduce ghosting artifacts associated with Fourier transform in SM. **iii)** Complex thresholding: Complex thresholds were applied to remove noise in the non-tissue regions in the phase images. **iv)** Susceptibility measurement: Free ROI drawing in SPIN (MRI Institute for Biomedical Research, Detorit, MI, USA) was used to draw ROI to measure susceptibility in the brain regions. Only positive susceptibility values within the ROI were considered for iron measurement. Susceptibility values measured in the SWIM images was taken as linearly proportional to the iron content within the tissue (2).

Results: SM corresponds to the presence of iron in regional brain tissues. A trend was observed showing the correlation between the iron deposition and age in the putamen. Mean susceptibility value in the young was close to zero. It was increased in the middle age and older groups with a 16 units difference between the middle age and older group (Figure 1).

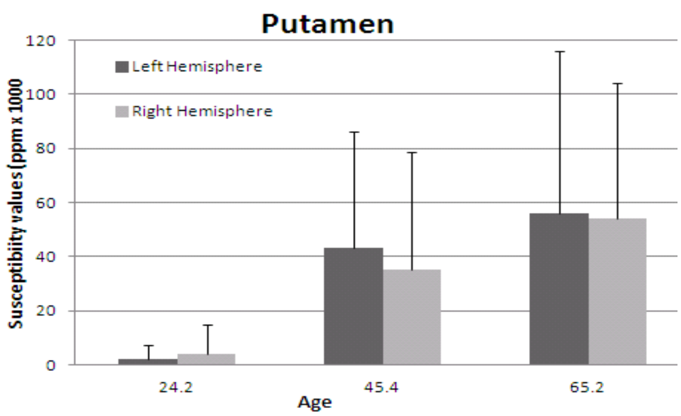

Figure 1: Susceptibility values on y-axis are multiplied 1000. X axis shows different age groups.

Discussion: A Recent study showe d a correlation between the susceptibility maps, generated using SWIM, and the measurement of iron content using X-ray fluorescence (2). Voxel to voxel based comparison between these two modalities showed that 1μg Fe/g brain tissue corresponds to 0.39~0.41ppb susceptibility values. We observed increases in iron deposition in the putamen even in middle aged healthy subjects in this small sample size pilot study. The increases in iron deposition with age detected with SWIM are consistent with previous studies (3). Future longitudinal studies with large sample size are warranted to confirm the findings of this study and to explore the potential to use SM as a biomarker to assess the rate of brain aging as well as the efficacy of interventions such as aerobic exercise training to prevent or slow brain aging.

Reference: (1) Haacke et al. J Magn Reson Imaging. Sep; 32(3):663-76, 2010. (2) W. Zheng et al. Proc. Intl. Soc. Mag. Reson. Med 19 (2011). Hallgrena and Sourander, J. Neurochem. 3(1): 41, 1958.