# In vivo estimates of regional iron deposition in young and elderly human brains

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## Introduction

Convergent postmortem and in vivo data indicate that deep gray matter brain structures accumulate ferritin at different rates throughout adult aging. The structures affected support motor functioning, and increasing iron deposition may contribute to age-related motor slowing. Iron can be measured in vivo with MR imaging because of iron's effect on signal intensity, causing signal darkening on T2* and T2-weighted images that is greater with increasing B0 field strength. By estimating the relaxivity increase from 1.5T to 3.0T, the MR Field Dependent Relaxivity Increase (FDRI) can be calculated. Brain iron is in ferritin molecules, which prolong transverse relaxation rates ($R_2$) linearly with field strength, and can be quantified with FDRI, where higher FDRI indexes greater local iron concentration.[1,2] In addition to relaxivity, MR gradient-echo image phase is influenced by local iron, and thus forms the basis for another method for iron quantification, Susceptibility-Weighted Imaging (SWI), which does not require scanning at two field strengths.[3] We compared these approaches to measurement of regional brain iron in healthy young and elderly volunteers.

## Methods

The young group comprised 5 men and 6 women (age 24.0+2.4 years); the elderly group comprised 6 men and 6 women (age 74.4+7.6 years) and scored within the normal range on a dementia screen.

Susceptibility-weighted imaging (SWI) at 1.5T was done with a 3D SPGR (TR/TE=58ms/40ms, $512^2$ over 24-cm FOV, flow compensation, 62 2.5-mm axial slices).[3] Other data included a structural 3D SPGR (TR/TE=28/10 ms, $256^2$) and 2D GRE acquisitions (TR/TE1/TE2=600/3/7ms) for B0 fieldmaps. Phase images from SWI were unwrapped with FSL Prelude and high-pass filtered (Hanning, 32x32).

Field Dependent Relaxivity Increase (FDRI) imaging was done at 1.5T and 3.0T with two multi-shot spin-echo EPI (TR/TE1/TE2 6000/17/60 ms, 256x192, 2 NEX, 24 interleaves, 62 2.5-mm axial slices 24-cm FOV) in addition to a 3D SPGR (TR/TE=8.1/3.3 ms). All data were registered to a common atlas, SRI24[4], at a 1-mm isotropic resolution.

Regions of interest were manually drawn on group-average FDRI coronal images, registered in common space, and were samples of bilateral globus pallidus (GP), caudate nucleus (Caud), putamen (Put), thalamus (Thal), substantia nigra (SN), red nucleus (RN), and frontal white matter (WM). Iron metrics were FDRI=$(R2_{3T} - R2_{1.5T})/1.5$, and SWI was the average ROI phase in radians.

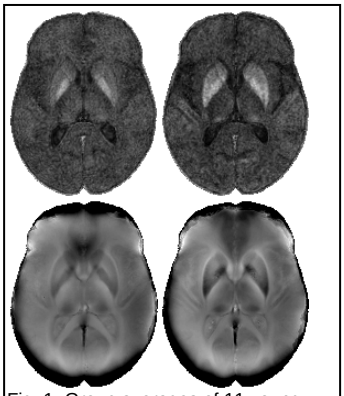

Fig. 1. Group averages of 11 young (left) and 12 elderly (right) subjects in common space. Top: FDRI: bottom: SWI. Note the greater presence of iron signal in the putamen of the elderly relative to the younger group.

## Results

Higher FDRI and lower SWI values indicate greater presence of iron. Group differences, based on bilateral measures, were identified with t-tests (Fig. 2). Both FDRI and SWI provided evidence for more iron in the elderly than young in basal ganglia. FDRI, but not SWI, revealed more iron in the two brain stem structures (SN and RD) of the elderly than young. The FDRI method revealed less iron in the WM and Thal samples of the elderly than the young, whereas the SWI method suggested greater iron in Thal of the elderly than young.

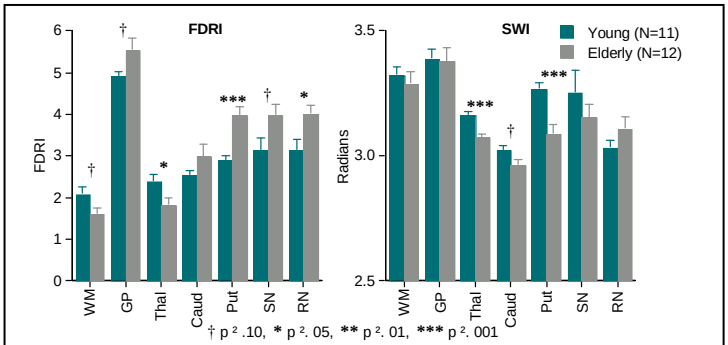


Fig. 2. Mean±SE FDRI (left) and SWI phase in radians (right) of each ROI in young and elderly groups.

## Discussion and Conclusion

Both methods detect the high concentration of iron in the GP regardless of age and the significantly greater presence of iron in the putamen with advancing age. Compared with FDRI, SWI was less sensitive in other regions of brain, perhaps because iron deposition is not the only contribution to susceptibility-induced phase effects. Further, perhaps due to its higher spatial resolution, SWI is more sensitive to subtle signal changes within a region than FDRI; for instance, the RN is highly visible but there are variations in the SWI signal even in this small structure. For studies of iron content in specific regions of basal ganglia, the SWI approach may be satisfactory, but for whole-brain surveys where specificity of the iron metric is required, FDRI is preferred. SWI has the advantage of high resolution, shorter imaging time, and acquisition at a single field strength. While FDRI requires more imaging time, two field strengths, and ideally across-study image registration for iron concentration calculation, FDRI is more specific to iron than SWI.

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## References

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