In Vivo Comparison of Three Quantitative MRI Techniques to Measure Brain Iron

C. A. Mallik[1], G. J. Barker[1], and D. J. Lythgoe[1]
[1]Centre for Neuroimaging Sciences, Institute of Psychiatry, London, United Kingdom

Introduction
Correlation of quantitative MRI with brain iron may provide a useful tool in the diagnosis and prognosis of neuropathology such as Multiple Sclerosis, Alzheimer's and Parkinson's Disease. Several different MR measures of brain iron have been proposed ([1] and references therein). The aim of this work was to compare three of the most promising, namely: transverse relaxation rate, magnetic susceptibility and magnetic field correlation (MFC) mapping.

Methods
Imaging: A gradient-echo spin-echo hybrid (GESE) [2] for R_2 measurement, a 3DGRASS susceptibility weighted sequence [3] and a symmetric and asymmetric spin-echo for MFC[4] were implemented on a Signa HDx 3T MRI (General Electric, Milwaukee, WI) scanner. To perform fair comparisons between techniques, published protocols were adjusted to achieve comparable brain coverage (32, 2 mm thick slices, and FoV 25.6x25.6cm), under the constraint of approximately equal, and patient tolerable scan times (6-8 minutes). All images were acquired axially on three healthy volunteers (aged 45-50). Sequence-specific parameters were: *GESE*: TR/TE=2750/34ms, echo spacing=0.86ms, matrix=128x128, #gradient echoes=32; *SWI*: TR/TE=35ms/20ms, matrix=384x384; *MFC*: TR/TE=3000/48ms, matrix=128x128, 180^o time-shift=0, -3.5, -7, -10.5, -14ms, #repeats=7, #shots=4.
Processing: *GESE:* magnitude images for each gradient echo were reconstructed offline (Viewit, NCSA, Champaign, IL) and fitted for R_2 as described in ref. [2], *SWI:* phase and susceptibility were calculated as described in [5] and [6]. *MFC:* All volumes were co-registered and repeat volumes averaged prior to fitting the expected signal equation as described in [4]. Regions of interest (ROI) were drawn within the red nucleus (RN), substantia nigra (SN), globus pallidus (GP), Putamen (Put), Thalamus (Thal) and frontal white matter (fWM) and plotted against reference iron levels [7].

Results
Figure 1 shows representative R_2, susceptibility and MFC maps (top row). R_2 measures in the ROIs (Fig. 1, bottom left) are consistent with previous studies [8], however MFC values are approximately double those previously measured [4]. Magnetic susceptibility is approximately half measured elsewhere [6] but has the greatest coefficient of determination in this group of 3 subjects. R^2 is the least for R_2 and although precision of R_2 appears to be improved (smaller standard deviation (sd)), in the Put, RN and SN, mean values ±1sd do not lie on the line of regression.

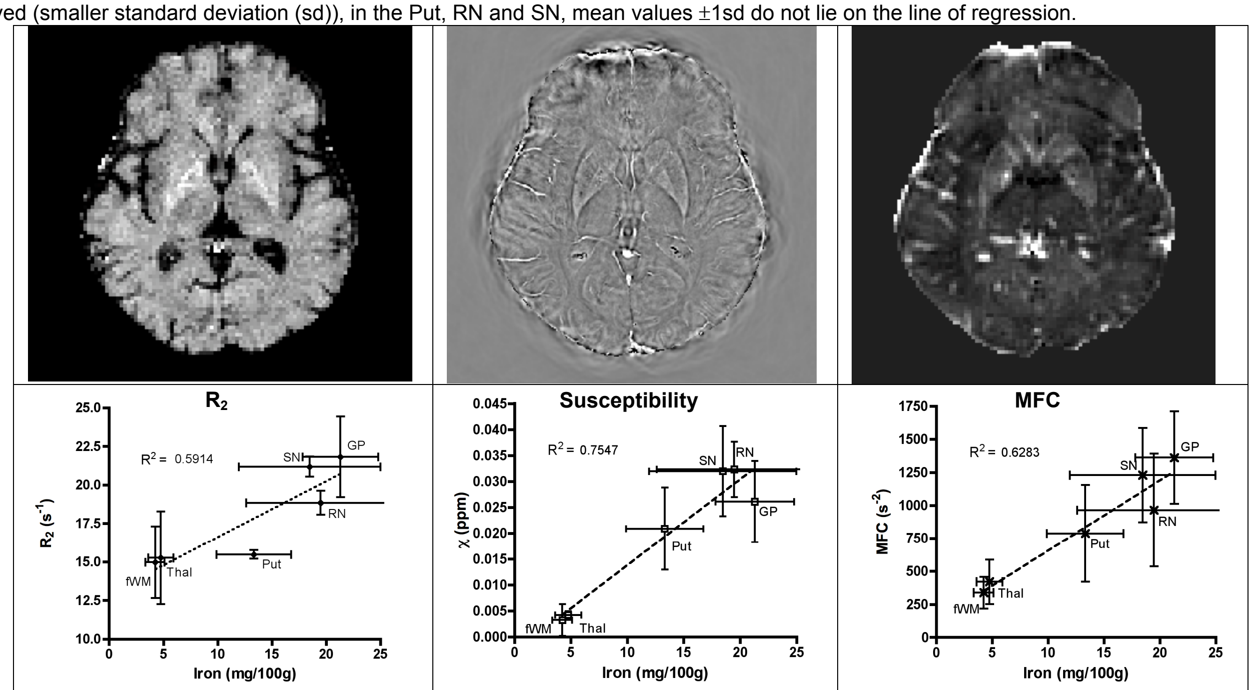

Figure 1. Representative maps for one subject produced by the three techniques (top). Correlation of MR measure ± sd against reference iron concentrations ± sd [7] for three subjects (bottom).

Discussion
Despite using the same echo time, which influences the MFC, MFC values are greater than previously measured, possibly due to the large variation in MFC values within each ROI for each subject. This will be investigated further. In addition to accuracy (assessed here in terms of strength of correlation to 'gold standard' published iron content values), other factors such as patient motion, pertinent to certain diseases such as Parkinson's, may be of consideration when choosing which iron-sensitive technique to use. MFC involves rapid acquisition of multiple volumes that are registered off-line, and may be preferable to GESE and SWI, which collect a single volume within the total scan time.

Conclusion
This preliminary work appears to show that magnetic susceptibility is more closely correlated with putative iron concentration than the other two measures and more control data will be collected to substantiate this. However, it may be that a combination of two or more of the different techniques will provide additional information on pathology [9] and this forms the basis of future work.

Acknowledgements: Karin Shmueli (NIH, Bethesda, USA) for the susceptibility mapping software.

References: 1. Haacke, EM, et al. Magn Reson Imaging 23 (2005). 2. Cox, E, et al. Proc. 16th ISMRM (2008) p1411. 3. Haacke, EM, et al. AJNR Am J Neuroradiol 30 (2009). 4. Jensen, JH, et al. Magn Reson Med 61 (2009). 5. Ogg, RJ, et al. Magn Reson Imaging 17 (1999). 6. Shmueli, K, et al. Magn Reson Med (2009). 7. Hallgren, B, et al. J Neurochem 3 (1958). 8. Gelman, N, et al. Radiology 210 (1999) 9. Warren, K, et al. Proc. ISMRM (2008) p506