Quantitative Comparison of Susceptibility-weighted Methods in Deep Grey Matter in Multiple Sclerosis

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Introduction: Multiple sclerosis (MS) is viewed as an inflammatory disease of the central nervous system (CNS), resulting in neurological disability over time. Magnetic resonance (MR) imaging has become essential in MS diagnosis focusing on white matter changes. Changes in grey matter (GM) have also been identified using MR imaging.[1] Accumulation of iron in deep GM structures has been shown to correlate with physical and cognitive dysfunction in MS.[2-4] Investigating the role of iron in progression of MS is a novel approach.[3,5-6] Susceptibility-weighted imaging is sensitive to changes in iron concentration. A new 3D multi-echo susceptibility-weighted imaging technique, SWAN, potentially offers better signal–to-noise properties and enhancement of iron effects than conventional 2D T2*-weighted gradient echo (GRE). This study improves on previous work by removing subjective region-of-interest based analyses.[7] In this study, we tested the hypothesis that SWAN is better than conventional, 2D T2* GRE for detection of signal changes in deep GM structures in healthy control (HC) subjects and MS patients.

Methods: Five healthy controls (HC) and 13 MS patients were imaged on a 3 T clinical MR scanner (Discovery 750; General Electric Healthcare, Waukesha, WI). Two susceptibility-weighted imaging sequences were acquired: a standard clinical 2D T2* GRE [TE/TR = 14.2 ms/575 ms, FOV = 240 x 192 mm^2, matrix = 288 × 192, flip angle = 20°, slice thickness = 3 mm] and a 3D susceptibility weighted angiography (SWAN; General Electric Healthcare) [TE/TR = 24.7 ms/40.6 ms, FOV = 240 × 192 mm^2, matrix = 320 × 224, flip angle = 15°, slick thickness = 2 mm). For each set of data, images were registered to a standardized structural brain atlas using FSL FLIRT. Image masks were prepared to isolate four deep GM structures (caudate nucleus (CN), globulus pallidus (GP), putamen (PUT), and thalamus (THL)) as well as the ventricles from a structural atlas. The masks were applied to images and measurements were recorded. For each patient, the average signal intensities of the deep gray matter structures were normalized by the signal intensity found in the cerebrospinal fluid (within the ventricles). Normalized signal intensities (nSI) were used to calculate signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) relative to ventricle signal. For each GM region, analysis of variance was used to compare nSI, SNR, and CNR by disease status and imaging sequence.

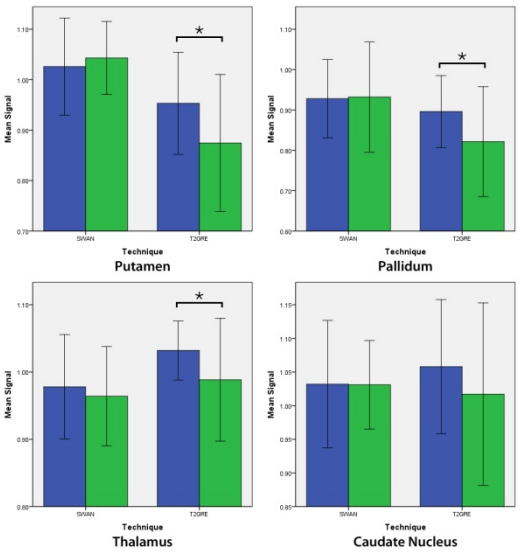

Figure 1. Two way ANOVA for change in nSI in HC (blue) and MS patients (green) in T2 GRE (right) and SWAN (left) for each region. Two way ANOVA had a interaction effect of p=0.000.*

Results: There was no significant difference in age between HC and MS subjects 37 y ± 8.2 y and 48 y ± 14.4 y (mean ± SD), respectively. A significant interaction effect was observed between region and imaging method (p<0.01). HC subjects had a significantly higher nSI than MS patients in T2* GRE (Figure 1) in each region, however only THL and CN had higher signal in HC subjects for SWAN. SWAN demonstrated a significantly higher average SNR than T2* GRE (p<0.01) in all regions 93.42 ± 21.81 and 68.70 ± 17.85, respectively. T2* GRE and SWAN offered similar CNR in the THL (3.11 ± 2.74 *vs* 3.07 ± 2.24, p>0.05) and CN (2.40 ± 1.65 *vs* 3.12 ± 2.78, p>0.05). T2* GRE had better CNR than SWAN in the PUT (9.77± 7.42 *vs* 3.63 ± 2.16, *p=0.05)*) and GP (13.36 ± 7.13 *vs* 7.00 ± 5.29, p=0.02).

Discussion: Larger changes in nSI from HC to MS patients were observed in T2* GRE than SWAN making iron-related effects in MS patients more distinguishable in T2* GRE (Table 1). An interaction effect in SWAN and inconsistent signal patterns make it more difficult to interpret than T2* GRE when detecting changes in deep GM structures. A consistent signal pattern (in each region, HC subjects always had higher signal than MS patients) may make T2* GRE easier to use when detecting changes in deep GM structures. The higher SNR observed in SWAN is very desirable and may offer a qualitative advantage clinically, but both SWAN and T2* GRE images had high SNR > 20 potentially making neither qualitatively better than the other, though excess SNR could be converted into better resolution or shorter scan time.[8] Higher CNR found in T2* GRE potentially makes better separation of deep GM tissues from other structures. These results suggest that at 3 T T2* GRE may be better for detecting susceptibility-related changes in deep GM structures because of the higher sensitivity to nSI changes and increased CNR.

Status	Region	T2* GRE	SWAN
MS	CN	1.02±0.07	1.03±0.03
	GP	0.82±0.07	0.93±0.07
	PUT	0.87±0.07	1.04±0.03
	THL	0.99±0.05	0.96±0.04
HC	CN	1.05±0.05	1.03±0.05
	GP	0.90±0.05	0.93±0.05
	PUT	0.95±0.05	1.02±0.05
	THL	1.03±0.02	0.98±0.04

Table 1. Summary of normalized signal (nSI) for disease status, region, and technique.

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