Shell versus Solid Geometry of MS lesions on Phase and QSM

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Target audience: Those interested in the appearance of complex lesion geometry on QSM

Purpose: There is debate over the iron distribution pattern in multiple sclerosis (MS) lesions[1,2]. Solids and shells (rings in 2D section) of iron may generate similar field patterns, making the distinction between these two geometries difficult on phase images that reflect only the magnetic field. This difficulty can be resolved using QSM[3]; by deconvolving the field, the true lesion shape can be recovered from the phase images. To confirm that the QSM algorithm faithfully reconstructs the geometries under question, experimental phantoms with mock MS lesions were created and imaged; *ex vivo* and *in vivo* lesion geometries were also examined.

Methods: *Phantom Imaging:* Solid and shell lesions (~1cm diameter) of varying super paramagnetic iron oxide (SPIO) nanoparticle[4] concentrations (5ug/ml to 1000ug/ml) were individually embedded in 50mL plastic tubes of one percent agarose. Tubes were scanned using a multi-echo GRE pulse sequence on a 3T scanner (GE Medical Systems, Milwaukee, WI) with a single-channel wrist coil. Matrix size: 256x64x72, voxel size: 0.5x0.5x0.5mm, 11 echoes, TE_1/ ΔTE /TR: 4.65 ms/5.06 ms/60.08ms. Local field images were generated using the SHARP method[5]. QSM images were reconstructed from complex MRI data [3]. Phantom results were qualitatively compared to *ex vivo* MS lesions as well as to *in vivo* calcifications and microbleeds.

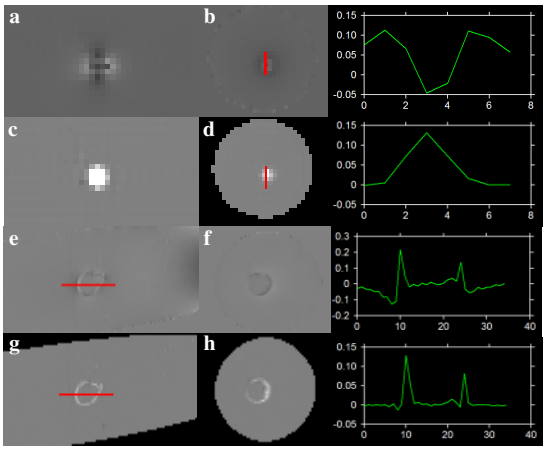

Figure 1: SPIO solid and shell phantom lesions (~1 cm diameter). (a) Local field estimate and (c) QSM for solid SPIO with (b) and (d) showing the corresponding cross-sectional views; (e) local field estimate and (g) QSM for shell SPIO with (f) and (h) showing the corresponding cross-sectional views.

MS Lesion Imaging: MS formalin-fixed brain specimens embedded in one percent agarose were imaged on a 7T Siemens scanner with a 24-channel head coil using a multi-echo GRE sequence with the following parameters: $TE_1/\Delta TE/TR$: 4.33ms/8.35ms/50ms,3 echoes, voxel size: 0.312x0.312x0.5mm. Microbleed and calcification images were taken from a previously published study: [6].

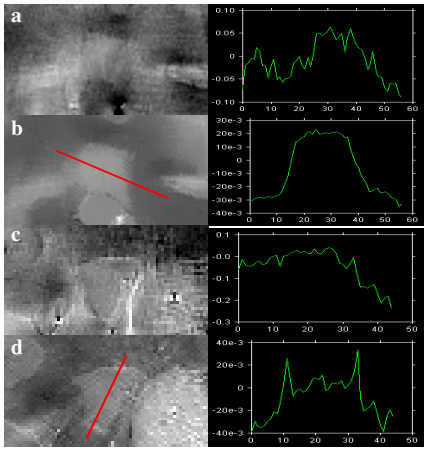

Figure 2: *Ex vivo* MS lesions. (a) Local field and (b) QSM of a solid lesion; (c) local field and (d) QSM of a mixed solid-shell lesion.

Results: SPIO geometric phantoms were successfully reconstructed in all cases. Figure 1 shows accurate QSM reconstructions for solid and shell lesions, while the phase images appear shell-like in both cases. Figure 2 shows exemplary slices of MS lesions that appear as solid and mixed solid-shell geometries. Figure 3 shows *in vivo* QSM of a solid calcification and a shell microbleed[6].

Conclusion: Our phantom data demonstrate that QSM successfully depicts solid and shell lesions of susceptibility, while phase imaging fails to distinguish them. Tissue lesions tend to be of more complex geometry, possibly making it difficult to have specific patterns on phase imaging. As the MS case demonstrates (Fig.2), deconvolution of phase images by QSM can clearly demarcate the lesion distribution even for complex lesion geometries.

References:

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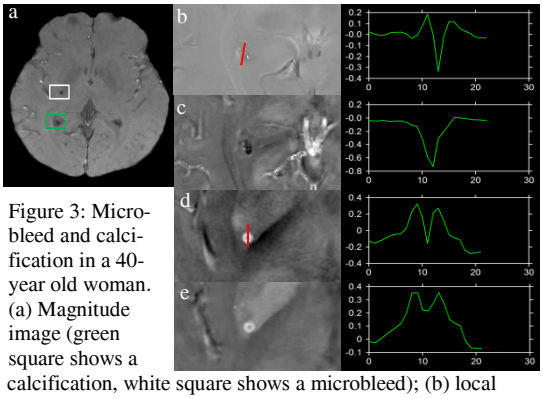

Figure 3: Microbleed and calcification in a 40-year old woman. (a) Magnitude image (green square shows a calcification, white square shows a microbleed); (b) local field and (c) QSM of solid calcification; (d) local field and (e) QSM of shell microbleed lesion.