Artefact removal in high phase gradient regions in susceptibility weighted images.

Amanda Ching Lih Ng[1], Shawna Farquharson[2], Sonal Josan[3], and Roger J Ordidge[1]

[1]*Dept of Anatomy and Neuroscience, The University of Melbourne, The University of Melbourne, VIC, Australia,* [2]*Imaging, The Florey Institute of Neuroscience and Mental Health, Melbourne, VIC, Australia,* [3]*Siemens Healthcare, Melbourne, VIC, Australia*

Target audience:

This abstract will be of interest to researchers and clinicians that use susceptibility weighted imaging (SWI), particularly at high field strengths.

Purpose: SWI processing traditionally involves homodyne filtering of the raw complex image data to simultaneously unwrap and high pass filter the phase[1]. In regions where there are high phase gradients, e.g. at air-tissue interfaces, homodyne filtering may inadequately unwrap and filter the phase, resulting in substantial artefacts that appear hypo-intense on the SWI image. Such artefacts can lead to problems in the assessment of important vascular structures located in or near these regions of high phase gradients, e.g. in brain regions surrounding the sinuses. Although more pronounced at higher field strengths (e.g. 7T), this problem is an issue for SWI data at all field strengths. Here we investigate a post-processing technique that uses a combination of phase processing applied in quantitative susceptibility mapping (QSM) analysis and homodyne filtering, with the aim of reducing high phase gradient artefacts present in SWI images.

Methods: SWI data from 5 healthy volunteers was acquired on a Siemens 7T MRI with a Nova 32 Channel head coil: TE/TR=15.3ms/20ms, FA=15°, matrix=896×728×144, voxel size=0.25×0.25×1mm^3, iPAT=3, TA=8:31min. The magnitude images were bias field corrected using N4[2], then used to create a brain mask with FSL BET[3]. QSM phase processing was applied: the raw phase was unwrapped using Laplacian-based phase unwrapping[4], followed by bias field correction using V-SHARP[5]. The unwrapped and filtered phase was then combined with the bias field corrected magnitude to form a bias corrected complex image. Homodyne filtering was then applied to this complex image to produce the phase used for the SWI calculations. Traditional SWI images were composed by applying homodyne filtering directly to the raw complex data to produce the phase for the SWI calculations. SWI and magnitude images using the traditional and the proposed phase processing methods were compared. The difference in the results generated using these techniques was assessed by subtracting the SWI data generated using the proposed processing technique from the traditional technique data for each subject.

Results: SWI images produced using the proposed processing steps have fewer artefacts than SWI images produced using traditional phase processing (figure 1). Compared to the magnitude image, the proposed SWI images do not demonstrate noticeably increased signal loss artefacts.

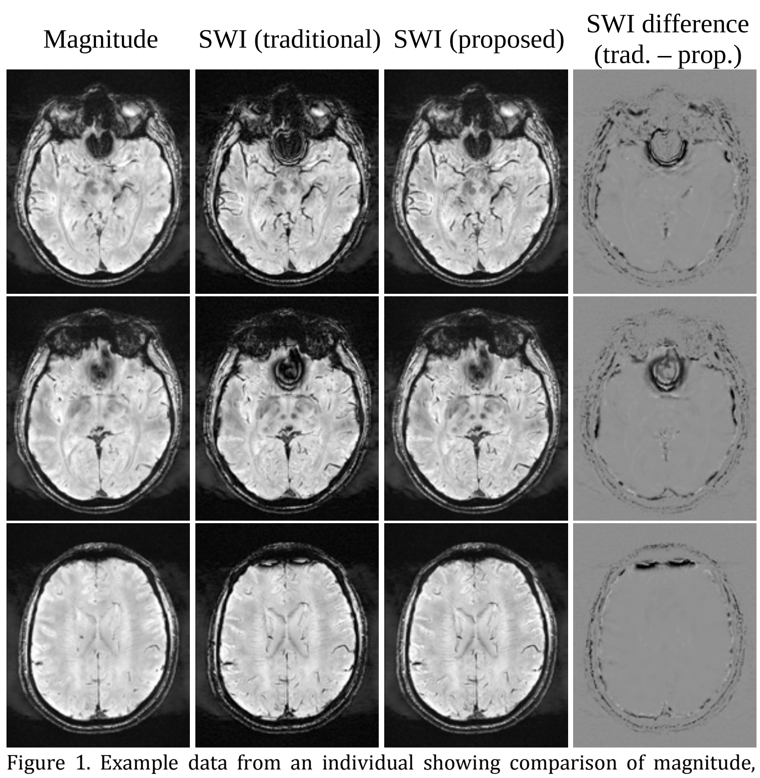

Figure 1. Example data from an individual showing comparison of magnitude, traditional SWI processing and proposed SWI processing. The intensity range is [0 100] for columns 1 to 3 and [-50 50] for column 4.

Discussion: SWI uses local changes in the phase to attenuate the magnitude image and emphasize voxels with higher susceptibility than the surrounding voxels, such as voxels containing veins. QSM, on the other hand, depends on the non-local effects of susceptibility on phase to estimate voxel-wise susceptibility values. As such, the phase processing requirements of the two methods are quite different. For SWI, macroscopic phase differences, such as in the basal ganglia, should be reduced; otherwise, veins in this region will be obscured. In contrast, QSM relies on the accuracy of these macroscopic phase differences to correctly estimate the susceptibility of brain structures. High pass homodyne filtering reduces the macroscopic phase differences, however is ineffective at removing high gradients near the sinuses. V-SHARP is successful at reducing phase changes due to susceptibility sources outside of the brain (e.g. sinus air spaces), while maintaining macroscopic phase differences due to internal susceptibility sources. By combining the two methods, we are able to remove the high gradients that cause signal loss in traditional SWI processing, while maintaining the required local phase-based attenuation in voxels containing veins. Although the proposed method takes longer to compute due to the iterations in V-SHARP, these results clearly demonstrate improved artefact removal and greater integrity in SWI images.

Conclusion: The combination of Laplacian-based phase unwrapping, V-SHARP bias field correction and homodyne filtering effectively reduces the signal loss artefacts apparent in SWI images in areas of high gradients.

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