

Phase singularities at fringelines result in artifactual microhemorrhages in SWI

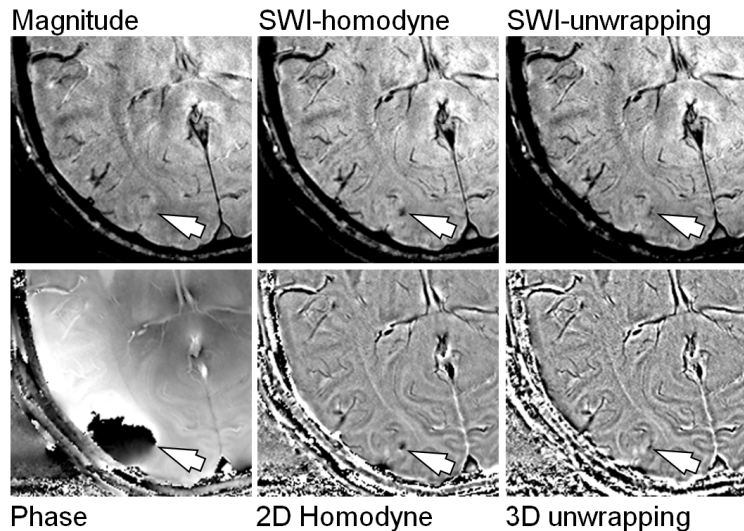
John Anthony Butman^{1,2}, Ningzhi Li², Wen-Tung Wang², David Joy², and Dzung Pham^{2,3}

¹Radiology and Imaging Sciences, Clinical Center of the National Institutes of Health, Bethesda, MD, United States, ²Center for Neuroscience and Regenerative Medicine, Bethesda, MD, United States, ³Uniformed Services University of Health Sciences, Bethesda, MD, United States

Introduction: Susceptibility weighted imaging (SWI) using 3D gradient recalled-echo (GRE) susceptibility weighted imaging (SWI) is increasingly used for detection of intracranial microhemorrhage, the MR imaging hallmark of TBI (1). Susceptibility effects generate contrast in two ways. Magnitude contrast results from differential degrees of intravoxel dephasing (resulting in T2* decay and signal loss) between adjacent voxels. Phase contrast results from differential phase accumulation between adjacent voxels due to local differences in field strength. Thus, both magnitude and phase images exhibit TE dependent susceptibility contrast. Combining phase and magnitude images in an appropriate manner results in a single image in which the susceptibility contrast seen in the magnitude image is emphasized. A crucial step in processing these images is the removal of unwanted phase wraps from the phase image. A branch cut (phase wrap) which traverses the image, or form a closed loop is referred to as a *cutline*. Phase wraps may also terminate at a singularity or pole within the image, and is then referred to as a *fringeline*. Here we report that the 2D homodyne filtering method of processing SWI, as implemented clinically, can result in artifacts mimicking microhemorrhage on phase emphasized SWI when fringelines are present.

Materials and Methods: SWI was performed on a 3T Siemens Biograph mMR system running version syngo MR B18P software using the product 3D GRE sequence and the product SWI processing. Contrast parameters were: TR 64 ms TE 25 ms flip angle 20°. Geometric parameters were: axial acquisition, matrix 448x343, 72 slices, in plane resolution 0.5x0.5 mm², 2 mm slice thickness. Acceleration parameters were: GRAPPA 2, no partial fourier in either phase or slice direction. With these parameters, whole head coverage was obtained with a scan time of 9 minutes 47 seconds.

Post processing: Magnitude and phase images were saved. Filtered phase (generated by homodyne filtering) and phase emphasized SWI images (generated by multiplying the phase and magnitude images according to (2)) were generated using the TWIX software on the scanner console. In addition, we processed the phase images using a 3D phase unwrapping procedure followed by high pass filtering (3). Phase emphasized SWI images were then generated in a manner similar to that used by the scanner.



Results: An artifactual microhemorrhage is illustrated in the figure (right). The arrow points to a location in the right occipital lobe which appears normal on the magnitude image. On the SWI image generated by homodyne processing, there appears to be a microbleed at the same location. Inspection of the corresponding homodyne filtered phase image demonstrates a punctate phase singularity at this point. Inspection of the wrapped phase images show that this point occurs precisely at the free end of a fringeline. Using a 3D global phase unwrapping procedure before performing the high pass filtering handles the singularity at the end of the fringeline more gracefully. The corresponding phase emphasized SWI image does not give rise to the artifactual appearance of a microbleed.

Discussion: Although in most cases the branch cuts (phase wraps) in MRI phase images of the brain form cutlines that extend across the brain, in some cases they form fringelines which terminate at a pole or singularity which cannot be handled by 2D homodyne high pass filtering methods without the introduction of artifactual microhemorrhages. This artifact occurs with current clinically implemented SWI processing and should be suspected when microhemorrhages are identified on phase emphasized SWI images but are not found on the corresponding magnitude images. Unfortunately, production of the raw (wrapped) phase images is typically suppressed in clinical SWI processing, so that identification of the cause of this artifact can be difficult. Implementation of 3D unwrapping methods may minimize this artifact, but this has not yet been explored systematically. The incidence and precise conditions in which fringelines appear has not yet been investigated.

Conclusion: An artifact which mimics the appearance of intracranial microhemorrhage arising from 2D homodyne SWI processing of gradient echo images is described. Since SWI detects microhemorrhages that cannot necessarily be confirmed on other sequences, one must be cognizant of this artifact to avoid overestimation of pathology, particularly TBI. Implementation of 3D unwrapping methods may minimize this artifact.

References:

1. Rauscher, A and Witoszynskij, S "Processing Concepts and SWI Filtered Phase Images" pp. 89-102 in "Susceptibility Weighted Imaging in MRI" Eds. Haacke, E and Reichenbach, J., 2011, John Wiley and Sons, pub.
2. Haacke EM, Mittal S, Wu Z, Neelavalli J, Cheng YC. Susceptibility-weighted imaging: technical aspects and clinical applications, part 1. AJNR Am J Neuroradiol 2009;30:19-30
3. Li N, Wang W-, Sati P, Pham DL, Butman JA. Quantitative evaluation of phase processing approaches in susceptibility weighted imaging. Progress in biomedical optics and imaging - proceedings of SPIE; 2012.