Reduction of Artifacts in Susceptibility Weighted Imaging

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Introduction: In susceptibility weighted imaging, complex division of the original images and low-pass filtered images is used to generate phase images in which the slow-varying background phase is removed (1,2). A 3D phase mask is then constructed using the filtered phase images. The phase mask is multiplied to the original magnitude images multiple times to generate susceptibility weighted images. When the filter size is too small, the large residual background phase in regions of severe field inhomogeneity can obscure the visibility of venous vasculature in these regions. When the filter size is too large, the phase contrast of small veins is adversely reduced. In this study, we demonstrate the degree of artifact in phase masks as a function of filter size. Minimum-intensity projection (mIP) is commonly used for the display of venous vasculature. Image artifacts can also arise from mIP. In axial projection, voxels in air and bone can be in the path of projection in peripheral regions of the brain due to the nature shape of the brain. The low intensity in air or bone results in the disappearance of signal from brain tissue, including veins, in the projection image in that region. The low intensity of air and bone also make mIP impractical for sagittal and coronal projections of whole-brain SWI data. We present a volume-segmented mIP (VS-mIP) approach to eliminated this artifact.

Methods: SWI data were acquired on a GE 3T scanner with a size of 512x384x64 and TE/TR/α=20ms/34ms/20^o. The field-of-view was 26cm×19.6cm and the slice thickness was 1.0mm. Hamming window was used for low-pass filtering to remove background phase. A slice-by-slice segmentation was manually conducted to remove the air region and the non-brain tissue, such as scalp bone, skin, and intracranial epidialum. A 3D binary mask was built based on the segmentation so that the voxels in the brain region have a value of "1" and the voxels in air or non-brain tissue have a value of "0". The 3D binary mask was applied to the 3D phase mask so that all the voxels in air and non-brain regions have a value of "0". The 3D SWI image was obtained by applying four multiplications of the 3D phase mask to the original 3D magnitude images. The mIP algorithm was modified so that it discards the voxels with intensity 0 along the path of projection. The voxel with non-zero minimum intensity is projected onto the final image.

Results: Figure 1 shows the mIP of 3D phase masks obtained with low-pass filter sizes of 64×48 (a), 96×72 (b), 128×96 (c), 192×144 (d), and 256×192 (e) with brightness adjusted. Phase artifacts at the orbitofrontal and lateral temporal regions, as indicated by thick arrows, are reduced with a larger filter size. The reduction of contrast of medium size veins becomes noticeable when a filter of 256×192 is used. The filter size of 192×144 is determined to be optimal in this scan. Volume-segmentation was applied to the phase masks. Figure 1f shows signal recovery at peripheral regions of the brain using VS-mIP of the 3D phase mask (192×144). Figure 2 shows the axial projections of SWI with conventional mIP (a) and VS-mIP (b).

Discussion: The venous contrast in the phase mask is slowly reduced in the veins when the filter size is increased. The artifact in Figure 1 can be severe in regions with large field inhomogeneity, such as orbito-frontal region and lateral temporal regions. The residual background phase can be much larger than the susceptibility phase in the veins. When the SWI data includes regions with severe field inhomogeneity, a large filter size should be used in low-pass filtering. The optimal selection of filter size is also determined by the region of interest. A small filter size will be optimal if the region of interest does not include regions with severe field inhomogeneity. In this study we also observed that signal loss can occur in a large portion of the peripheral regions of the brain during mIP. A VS-mIP approach is effective in recovering the signal loss in these regions.

References: 1) Reichenbach, JR et al., Radiology 1997;204:272-7; 2) Haacke, EM, et al., MRM 2004;52:612-8.

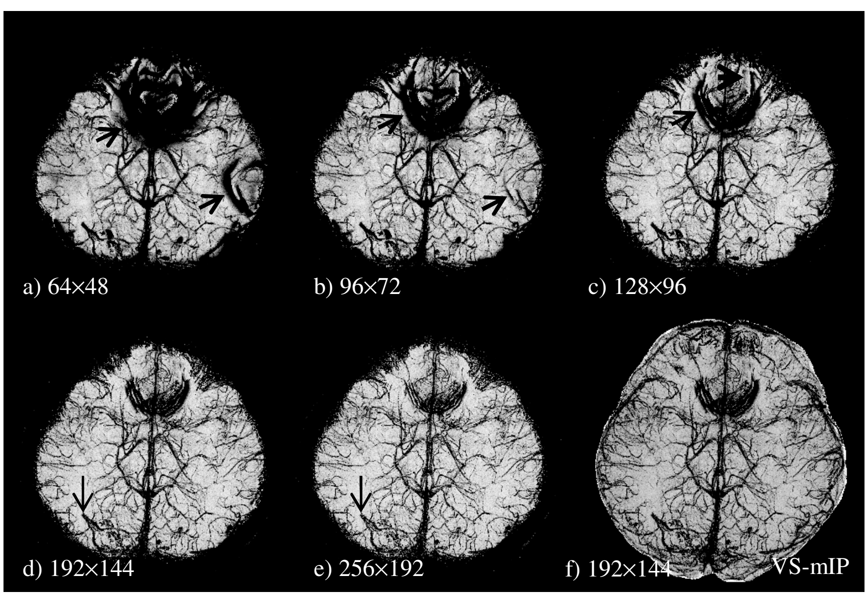

Fig. 1. mIP of phase mask at different sizes of Hamming window (a-e). Fig. 1f shows the signal recovery at peripheral regions of the brain using VS-mIP.

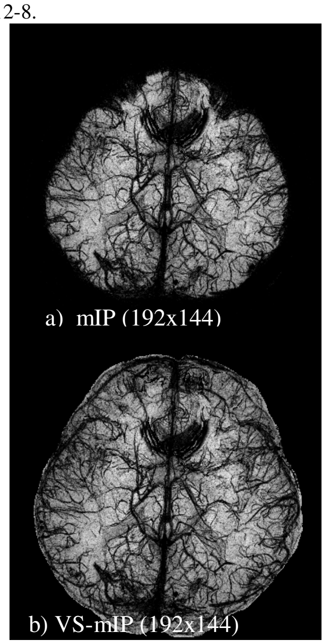

Fig. 2. SWI with conventional mIP (a) and VS mIP (b).