MR Susceptibility Weighted Imaging with Multi-Echo Acquisition

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Introduction: In MR susceptibility weighted imaging (SWI), venous vasculature has a lower phase and magnitude than background tissue due to the susceptibility difference between venous blood and parenchyma [1]. For veins in parallel to the B0 field at 3T, partial volume signal cancellation between veins and background tissue reaches the maximum when the phase difference in venous blood is -180^o at TE=28ms [2,3]. For veins not in parallel to the B0 field, a longer TE is desirable to reach the maximum venous contrast. On the other hand, susceptibility artifacts become more severe and signal-to-noise ratio (SNR) is reduced at a longer TE. A shorter TE is, therefore, advantageous in increasing SNR and depicting veins in regions with severe field inhomogeniety. The phase contrast is expected to reach the maximum when the phase difference between venous blood and parenchyma is at approximately -90^o in voxels with partial venous blood. As such, a shorter TE can also be advantageous in detecting the phase contrast for small veins. In this study, we present a multi-echo approach for the acquisition of three-echo SWI. Optimal venous visibility can be obtained using these three datasets.

Methods: The acquisition of three echoes was added to a 3D gradient-recalled echo pulse sequence. A fly-back gradient was placed in the middle of adjacent readouts to restore the flow-compensation in the latter echo. Multi-echo SWI data were acquired on a GE 3T scanner with a matrix size of 384x310x32, a FOV of 20cm×16cm, and a slice thickness of 1.6mm. The echo times were 19.7ms, 23.4ms, and 37.6ms, respectively. The TR was 47ms and flip angle was 20^o. The in-plane resolution was $0.52\times0.52mm^2$ and the voxel volume was $0.43mm^3$. High-order shim was applied prior to the scans to improve the field inhomogeneity. Flow compensation was applied along all three directions to reduce flow artifacts. The total scan time was 7 minutes and 46 seconds. In this study, a 66.7% partial echo acquisition was used to reduce TR. A projection onto convex sets (POCS) algorithm was used to reconstruct the partial echo datasets. A phase mask was generated for each echo using a 128x100 Hamming filter. The phase mask was multiplied to the magnitude images 4 times to generate the susceptibility weighted images.

Results: Figure 1 shows the minimum-intensity projection (mIP) of the phase masks (top) and SWI (bottom) at TE of 19.7ms (left), 23.4ms (middle), and 37.6ms (right). The overall venous contrast is higher in the phase masks with in a longer TE. Susceptibility artifact is more severe at a longer TE at the orbitofrontal region, as indicated by the arrows. In certain regions known to have high iron deposition, as indicated by the circles, small veins have a higher contrast in the images with a shorter TE. Low signal intensity in these regions due to shortened T2* reduces the visibility of small veins at the third echo. Some of the major veins and nearby small veins also have reduced visibility at the third echo, as indicated by the ellipse, due to substantial signal drop near the major veins at a longer TE.

Discussion:

To the best of our knowledge, this is the first study exploring the use of multi-echo acquisition for brain SWI, despite the previous use of a similar sequence with contrast media for artery and vein separation in the legs [4]. The preliminary results show that some of the veins are better visualized in SWI with a longer TE, and others are better depicted with a shorter TE. Multi-echo acquisition also enable us to combine the datasets acquired at different echo times to increase the signal-to-noise ratio at a high resolution, improve the visibility of veins, and reduce image artifacts. In summary, multi-echo acquisition can be used to provide improved visibility of veins with different sizes at different locations.

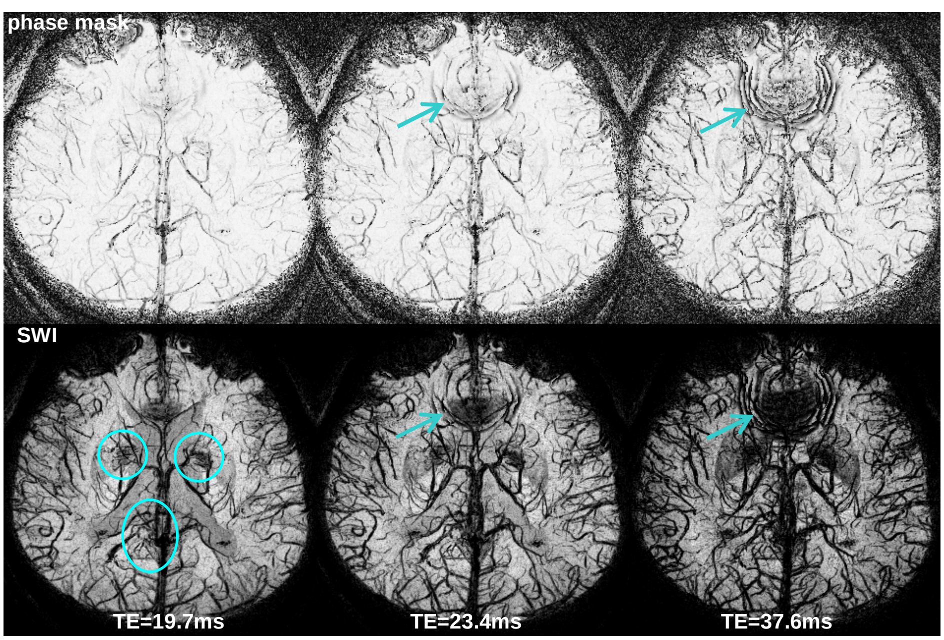

Fig. 1. The mIP of the phase masks (top row) and magnitude images (bottom row) of the first (left), second (middle), and third (right) echo. The regional susceptibility effect at the orbito-frontal cortex introduces artifact in the phase mask and SWI, as indicated by the arrows. The veins in several regions are better visualized at a short TE, as indicated by the circles and ellipse.

References:

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