Single Echo Simultaneous Angiography and Venography (MRAV) Techniques at 3T

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Introduction: Several techniques have been presented in the last year to acquire both angiographic and venographic information in a single acquisition (MRAV) using susceptibility weighted imaging (SWI). However, these techniques either require a double echo acquisition (1) or a single echo with flip angles that tend to compromise the quality of either the angiography or venography (2). In this work we develop novel acquisition and post processing techniques to improve the quality of single echo MRAV acquisition. The ability to collect MRAV data is an important clinical goal for analyzing a variety of clinical diseases including: stroke, trauma, tumors and multiple sclerosis.

Materials and methods: All SWI images were acquired at 3T with a resolution of $0.5x0.5x0.5mm^3$. Imaging parameters were TR=30ms, TE=20ms, FA=15°, and BW=50Hz/pixel or 160Hz/pixel. Maximum intensity projections (MIPs) to visualize the arteries were performed on the original magnitude data. Data was then downsampled to a resolution of $0.5x0.5x2.0mm^3$. SWI processing with the high pass filtered phase image was performed, and minimum intensity projections (mIPs) generated to visualize the veins. Two types of downsampling filters were compared: a simple crop of the K-space data, which is equivalent to a lower resolution acquisition, and a sliding window complex averaging filter. The sliding window filter takes the average of the complex signal (magnitude and phase) of four slices, advances a single slice, calculates the next average, and repeats until all slices are processed. In this way the resolution is reduced but the same number of slices as the original series is maintained. It also offers a distinct advantage over the original k-space data in that it used the high pass filtered phase in the complex downsizing process not the original phase.

Results: Using a higher bandwidth of 160 Hz/pixel as compared with 50 Hz/pixel dramatically reduces flow dephasing, improving larger vessel visibility at the cost of a reduced signal-to-noise ratio (SNR) (Figure 1). The high isotropic resolution ($0.5x0.5x0.5\ mm^3$) also helps to reduce dephasing across a voxel in fast flowing vessels such as the MCA, reducing flow losses. The original isotropic resolution data showed poor venous contrast in the phase and mIP images. The downsampled data ($0.5x0.5x2.0\ mm^3$), however, showed good venous contrast and improved SNR. The sliding window and k-space crop filters showed similar performance with the sliding window showing slightly better depictions of some small veins.

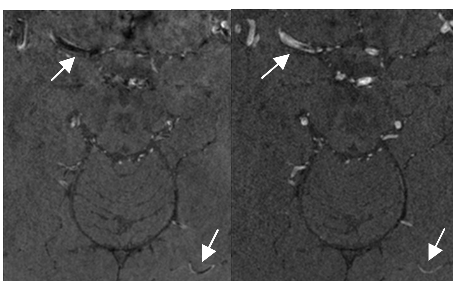

Figure 1. 50 Hz/pixel (left) shows almost complete loss of the MCA and losses in the middle of smaller vessels while 160Hz/pixel (right) shows minimal flow losses.

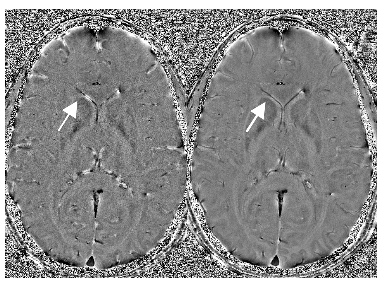

Figure 2. Isotropic phase image (left) shows veins switching from bright to dark depending on orientation. Downsampled image (right) shows higher SNR and more homogenous veins producing a better venography.

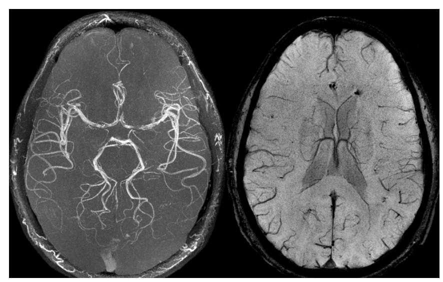

Figure 3. Maximum intensity projection (left) over isotropic data showing arteries and minimum intensity projection (right) over SWI processed downsampled image.

Discussion and Conclusion: The poor venous contrast observed in the isotropic data is due to the non-optimal aspect ratio of 1:1 (3) which causes the phase for certain orientations of veins to have the opposite sign (Figure 2). This lost contrast is fully recovered by downsampling the high resolution data to be a more optimal aspect ratio of 1:4 ($0.5x0.5x2\ mm^3$) resulting in conventional SWI venous contrast and improved SNR. The sliding window filter takes advantage of the fact that the high resolution data was collected by reconstructing the lower resolution slices in an overlapping pattern so the optimal partial voluming of smaller structures is guaranteed thus improving image quality. Further, Gibbs ringing is dramatically reduced compared to a truncated k-space approach. Also, isotropic data is more easily reformatted into another view and then the same process repeated which cannot be done with the conventional aspect ratio of 4:1. By collecting data with high isotropic resolution and higher bandwidth, flow related losses from higher order uncompensated effects can be reduced improving the quality of the MRA extracted from the SWI data even at long echo times (20ms). Downsampling this data to an optimal aspect ratio for SWI venography allows good venographic contrast to be recovered with good signal-to-noise despite the high resolution scans and high bandwidth.

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3. Xu Y, Haacke EM. The role of voxel aspect ratio in determining apparent vascular phase behavior in susceptibility weighted imaging. Magn Reson Imaging 2006; 24:155-160.