High Resolution MR Susceptibility Weighted Imaging with Partial 3D K-Space Acquisition

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Introduction: MR susceptibility weighted imaging (SWI) has recently shown great merit in the diagnosis of brain diseases related to venous vasculature [1,2]. A relatively long TE is typically used in SWI to achieve nearly optimal venous contrast. At the optimal TE, the venous blood in a voxel has out-of-phase partial volume cancellation with the neighboring stationary tissue, resulting maximal venous contrast in the magnitude images and in phase masks. For veins in parallel with the B0 field, the optimal echo time (TE) is 56ms at 1.5T and 28ms at 3T. The scan time for high resolution SWI can be fairly long even at 3T, in the range of 20-30 minutes, when large volume coverage of the brain is required. The scan time will be much longer at 1.5T for the use of a longer TE. This long scan time can hamper the use of SWI in routine clinical exams. In addition, the SWI data have relatively low signal-to-noise ratio (SNR) due to the T2* decay at a long TE. In this study, we investigate the use of partial k-space acquisition to reduce scan time and the use of 3D Fermi filtering in k-space to improve SNR. Partial k-space acquisition in both k_y and k_z is used to reduce the number of excitations, and therefore, scan time. Partial echo acquisition in k_x enables us to shorten TR without reducing TE.

Methods: Full k-space SWI data were acquired on a GE 3T scanner with a size of 512x384x64 and TE/TR/α=20ms/34ms/20°. The field-of-view was 26cm×19.6cm and the slice thickness was 1.0mm. The readout bandwidth was ±31.2kHz. The scan time was 14 minutes. An off-centered truncation window was applied to the full k-space data, resulting a partial k-space dataset with 336 sampling points along k_x, 252 views along k_y, and 52 views along k_z. Three-dimensional projection onto convex sets (POCS) was used in the reconstruction of the partial k-space data to generate 3D magnitude images. A 3D Fermi filter was also used to increase the SNR and reduce angular dependence of spatial resolution.

Results: The top row in Figure 1 shows the minimum-intensity projection (mIP) of the *magnitude* images with full k-space data (a) and partial k-space data reconstructed with 3D POCS (b). The phase contrast of the veins in phase masks was severely degraded with the 3D POCS reconstruction. Because the high spatial frequency component of the phase difference between the veins and background tissue is a major source of venous contrast in SWI, the requirement of POCS algorithm for slow-varying phase in the image domain was not satisfied. To avoid this drawback of the 3D POCS algorithm, zero-padding was used to reconstruct the phase images and phase masks. The bottom row in Figure 1 shows the mIP of *phase masks* with full k-space data (c) and partial k-space data reconstructed with zero-padding (d). The phase masks were multiplied to the magnitude images four times to obtain the susceptibility weighted images. Figure 2 shows the mIP of SWI with full k-space data (a) and partial k-space data (b). Views at the corners of (k_y,k_z) domain were unsampled to further reduce scan time. Figure 2 also shows the mIP of SWI with 3D Fermi filtering with full k-space data (c) and partial k-space data (d). The partial echo acquisition would reduce TR from 34ms to 31ms. Partial k_y and k_z acquisition would reduce scan time by 46.7%. The corner views in (k_y,k_z) were not used, resulting a further reduction of scan time by 10.0%. The overall reduction of scan time would be 56.0%. The venous contrast and visibility of small veins is noticeably reduced with the partial k-space data (Fig. 2d) compared to that with full k-space data (Fig. 1a).

Discussion: Partial k-space acquisition can substantially reduce the scan time. While this reduction of the scan time would make SWI more practical for routine clinical exams, the visibility of small veins is compromised. Three-dimensional POCS algorithm is effective in reconstructing the magnitude images, but not the phase images, from the partial k-space data. The phase constraint in the POCS requires a slow-varying phase in the image domain. This constraint is not satisfied in SWI in which large phase change can occur even in small veins. This study raises the need for developing a more effective reconstruction algorithm for partial k-space data in SWI. This study also demonstrates that the SNR of SWI can be improved by applying a 3D Fermi filter in k-space.

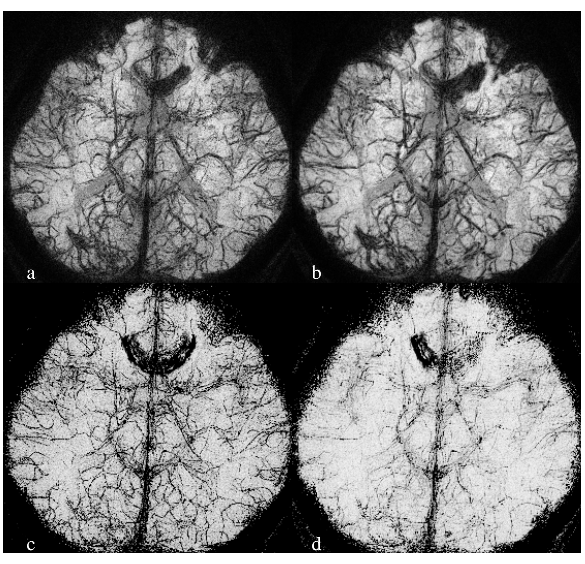

Fig. 1. The top row shows the mIP of magnitude images with full k-space (a) and partial k-space (b). The bottom row shows the mIP of phase masks with full k-space (c) and partial k-space (d).

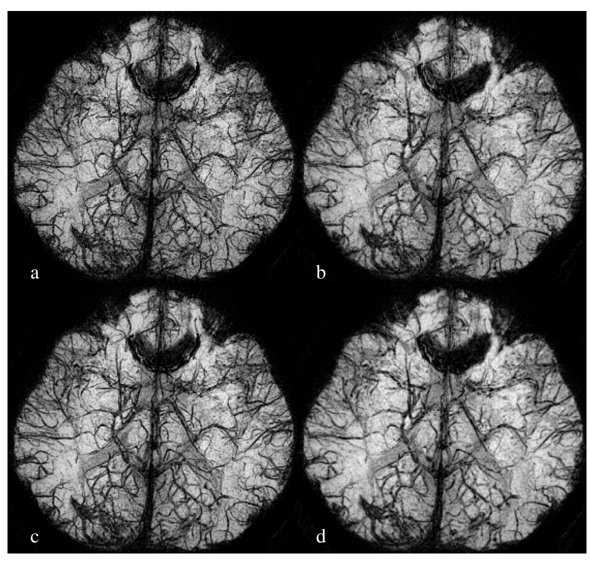

Fig. 2. The top row shows the mIP of SWI with full k-space (a) and partial k-space (b). The bottom row shows the mIP of SWI with 3D Fermi filter with full k-space (c) and partial k-space (d).

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