Susceptibility-weighted imaging of brain tumor patients at 7T using an autocalibrating parallel technique

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Introduction

Susceptibility-weighted imaging (SWI) is a powerful tool for high resolution imaging of the vasculature, aiding in the diagnosis of many pathologic conditions.[1,2] This technique is especially beneficial at higher field strengths where traditional sequences that measure cerebral blood volume suffer from severe distortions, rendering them inapplicable at 7T. Conventional SWI sequences involve long scan times on the order of 10 minutes at 7T for a 2 cm slab of coverage, which can result in patient discomfort and motion-induced artifacts. Previous work showed that simulating a 2-fold acceleration with GRAPPA in normal volunteers at 7T did not degrade vessel contrast from the full FOV acquisition and provided significantly elevated contrast compared to SENSE reconstruction.[3,4] In this study we have implemented a GRAPPA-based partially parallel imaging acquisition and reconstruction with multi-column multi-line interpolation[5] for accelerating SWI of brain tumors at 7 Tesla.

Methods

High resolution T2*-weighted brain MR imaging was performed on 6 healthy volunteers and 10 brain tumor patients using a 7T whole body MR scanner (GE Healthcare) using uniform excitation by a volume transmitter and reception by an eight channel phased-array head coil (Nova Medical). The susceptibility weighted imaging employed a 3D flow compensated, SPGR sequence with TE/TR=16/80ms, flip angle=20°, BW=62.5 kHz, and 24x24x2.8 cm^3 FOV. The full FOV scans utilized a 512x256x28 image matrix, while GRAPPA with R=2 was either simulated or acquired using a 512x146x28 image matrix with 16 ACS lines and reconstructed with a GRAPPA-based technique developed in our laboratory.[5] For the five patient scans with a GRAPPA-based acquisition, the nearly 2-fold reduction in time was sometimes traded to extend the coverage of the entire tumor. Phase masks were constructed from the raw complex data of each individual coil element through complex division by a low-pass filtered image and scaling the resulting negative phase values between zero and one.[1] The phase masks were then multiplied into the magnitude image from each coil *m* times and the resulting susceptibility-weighted images were combined by the traditional square root of sum of squares method. For the volunteer data, the conventional 64x64 filter with *m*=4 weighting was employed, while the patient scans were additionally processed with a 128x128 filter size and *m*=6 weighting to remove residual higher frequency phase wraps near the tumor. Minimum intensity projections (mIPs) through 15mm thick slabs were generated and thresholded at varying degrees in order to create regions from which to calculate contrast ratios of vessels compared to surrounding brain tissue.

Results and Discussion

Volunteer data: The mean contrast ratios for simulated and acquired normal volunteer datasets are displayed in Table 1. No statistically significant difference (p=0.7, Wilcoxon signed rank test) was found between the GRAPPA and full FOV acquisitions for both large and small vessels in all datasets, with GRAPPA experiencing only 3% and 2% deviations in large and small vessel contrast from the full FOV dataset. Figure 1 depicts this similarity in contrast between the two acquisitions, despite the nearly 2-fold reduction in scan time achieved with GRAPPA (full FOV: 10:59 min; GRAPPA: 6:12 min).

Patient data: Similar contrast ratios were observed for normal brain vessels of the brain tumor patients when projected at the same thickness as the volunteer data (p>0.1, Wilcoxon rank sum test). A trend towards heightened contrast was observed with increased filter size and *m* value in all patients, but this difference was not significant (p=0.06 for full FOV and p>0.1 for GRAPPA, Wilcoxon signed rank test). Figures 2 and 3 show representative SWI images of brain tumors for the full FOV and GRAPPA acquisitions. In these SWI images, performing a mIP is not necessary to visualize vessels, blood products, or radiation effects in the tumor region.

Conclusions

Susceptibility-weighted imaging is a promising technique at 7T and is feasible for use in patient studies. The implementation of parallel imaging with GRAPPA reconstruction allows a 2-fold reduction in scan time without compromising the contrast between veins and surrounding brain tissue. A larger filter size and m value may be implemented for patients where high frequency phase wraps cause artifacts near the tumor without adversely affecting large vessel contrast or the detection of smaller vessels. SWI can provide additional valuable information that may aid in characterizing brain tumors and monitoring treatment effects.

Table 1: Summary of small and large vessel contrast ratios

	Large vessel contrast ratio		***Small vessel contrast ratio***	
Volunteer data	*Full FOV*	*GRAPPA*	*Full FOV*	*GRAPPA*
simulated (n=6)	3.07 ± .38	3.32 ± .48	1.25 ± .15	1.32 ± .14
acquired 1	3.66	4.15	1.51	1.40
acquired 2	3.53	4.17	1.21	1.23
Patient data				
64 x 64 filter, m=4	2.95 ± .37	2.92 ± .18	1.38 ± .11	1.50 ± .20
128 x 128 filter, m=6	3.11 ± .41	3.00 ± .18	1.48 ± .15	1.62 ± .28

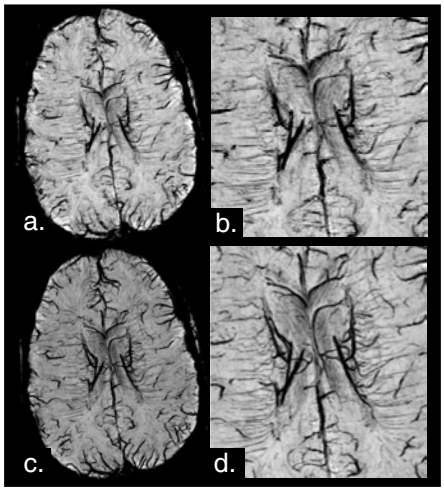

Figure 1. Normal volunteer SWI with mIP =15 mm for full FOV (a,b) and GRAPPA (c,d) acquisitions.

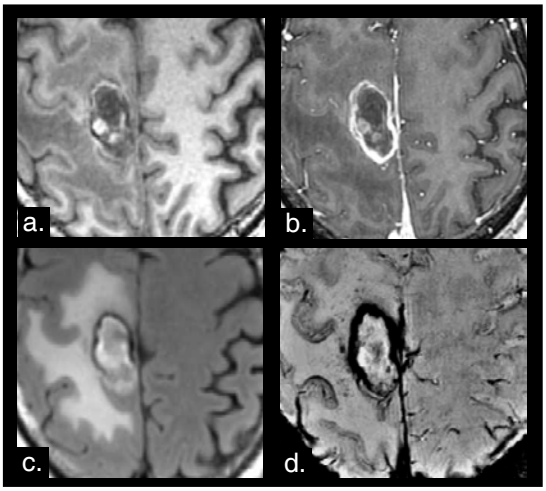

Figure 2. Full FOV SWI for a recurrent glioma patient post- therapy. In (a-c) corresponding 3T anatomical scans: (a) pre-Gd and (b) post-Gd T1 SPGR, (c) T2 FLAIR. In (d) 7T SWI.

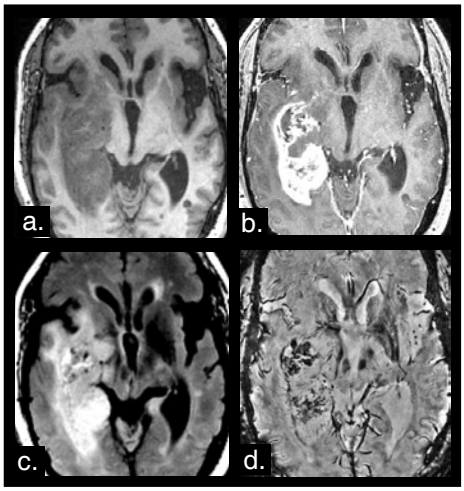

Figure 3. GRAPPA SWI for a glioma patient pre-therapy. In (a-c) corresponding 3T anatomical scans: (a) pre-Gd and (b) post-Gd T1 SPGR, (c) T2 FLAIR. In (d) 7T SWI.

References and Acknowledgements: [1] Haacke EM et al. MRM 2004;52(3):612-618. [2] Sehgal V et al. JMRI 2005;22(4):439-45. [3] Lupo JM et al. Proc. 14th ISMRM 2006. [4] Lupo JM et al. Proc 28th IEEE EMBS 2006. [5] Banerjee et al. MRM 2006;56(5):1075-84. This study was supported by UC Discovery grants LSIT01-10107 and ITL-BIO04-10148, and NIH grants R01 CA059880 and P50 CA97257.