Susceptibility-weighted imaging at 3T and 7T using multi-channel phased array coils and SENSE

J. M. Lupo[1], D. Kelley[2], D. Xu[3], D. B. Vigneron[3], S. J. Nelson[3]

[1]UCSF/UCB Joint Graduate Group in Bioengineering, University of California, San Francisco, CA, United States, [2]Global Applied Science Lab, GE Healthcare, San Francisco, CA, United States, [3]Surbeck Laboratory of Advanced Imaging, Department of Radiology, University of California, San Francisco, CA, United States

Introduction

Susceptibility weighted imaging (SWI) in an emergent technique for high resolution, distortion-free imaging of brain vasculature that is recently gaining importance in the clinical setting. The weighting relies on changes in phase that result from signal loss due to partial volume effects near venous vessels, typically requiring long echo times to obtain sufficient weighting.[1] As high field MR systems with multi-channel coil capabilities become readily available for routine clinical use, the need for faster acquisition times and efficient ways of combining multi-channel coil data without losing the phase information as a result of the reconstruction becomes apparent. Parallel imaging acquisitions and sensitivity-encoding (SENSE) reconstruction algorithms can be employed to speed up these long acquisition times as long as the concomitant decrease in SNR does not significantly affect the contrast between vessels and brain parenchyma.[2,3]

Methods

High resolution T2*-weighted images were acquired on eight healthy volunteers using a 3T GE Signa Echospeed system equipped with an EXCITE platform (GE Healthcare Technologies) and 8-channel phased-array coil (Medical Devices). One of the eight volunteers was also scanned on a 7T system equipped with a 16-channel phased-array coil (USA Instruments). 3D flow compensated, SPGR and GRE sequences were acquired at 3T with TE/TR=28/46ms, flip angle=20^o, BW=15.6 kHz, a 24x24x6 cm^3 FOV, and a 512x256x60 image matrix. For the 7T acquisition, three datasets for each sequence were collected at different echo times (8, 12, and 16 ms), with TR=100ms, flip angle=20^o, BW=62.5 kHz, a 24x24x2.8 cm^3 FOV, and a 512x256x28 image matrix. For conventional full FOV multi-channel acquisitions, phase masks were constructed from the raw complex data of each individual coil element through complex division by a low-pass filtered image to remove the effects of field inhomogeneity, 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 four times and the resulting susceptibility-weighted images were combined by either summing the images weighted by coil sensitivity profiles obtained from a low resolution PD-weighted fGRE scan (3T acquisitions) or the traditional square root of sum of squares method (7T acquisitions). SENSE reconstruction with a reduction factor of 2 was then simulated for each 3T acquisition to generate reduced FOV complex images which were then combined using complex coil sensitivity profiles before performing the susceptibility weighting. Minimum intensity projections (mIPs) through 20mm thick slabs were generated and thresholded at varying degrees in order to create regions from which to calculate contrast ratios of small and large vessels compared to surrounding brain tissue for the various SWI acquisitions.

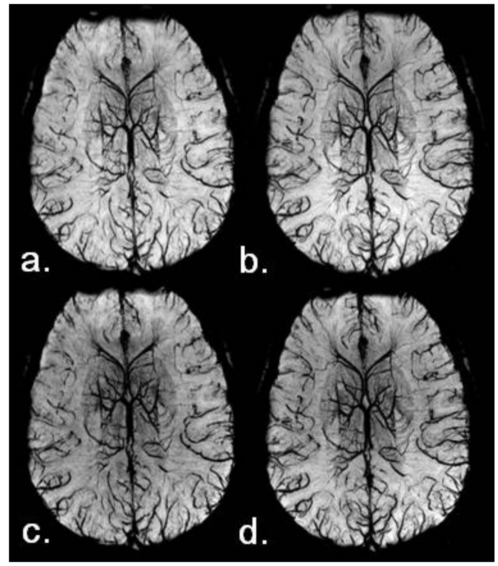

Figure 1: 3T SWI for a) standard GRE, b) standard SPGR, c) SENSE GRE, and d) SENSE SPGR acquisitions.

Results and Discussion

At 3T, the ratio of signal intensity (contrast ratio) between the large vessels and brain tissue is significantly higher ($p<.01$, Wilcoxon signed rank test) for the conventional GRE sequence compared to the SPGR; however, no difference was observed in small vessels (Figure 2). The addition of SENSE has no noticeable effect on the contrast resolution of small vessels.

Preliminary results at 7T show the feasibility of applying this technique. Figure 3 illustrates the increased difference in contrast for both large and small veins observed with longer echo times at 7T. This heightened contrast is more apparent between 8ms and 12ms TEs than for 12 and 16 ms TEs. Larger susceptibility distortions at 7T compared to 3T result in increased phase distortions at equivalent echo times. The GRE images show improved detection of smaller vessels compared to the SPGR at all TEs, with values ranging from 3-21%. The contrast resolution of larger vessels, however, is similar between the two sequences. Figure 4 shows the improved delineation of small vessels for the same brain region at 7T compared to 3T.

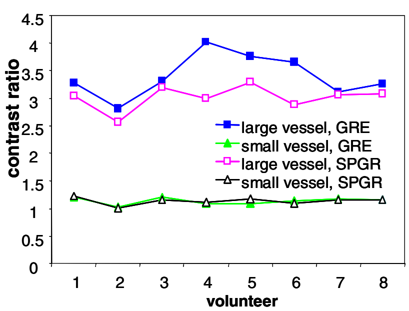

Figure 2: Contrast ratios for small and large vessels for standard GRE and SPGR sequences plotted individually for each volunteer .

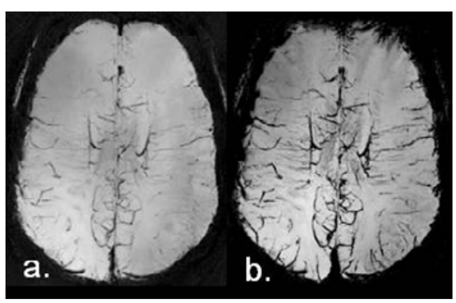

Figure 3: GRE SWI images at 7T collected at a) TE=8ms and b) TE=16ms.

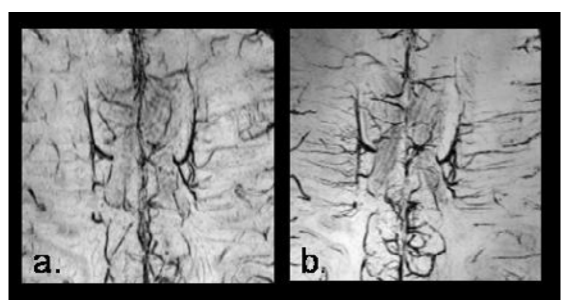

Figure 4: GRE SWI images at a) 3T (TE-28ms) and b) 7T (TE=16ms), enlarged to view small vessels.

Conclusions

Susceptibility-weighted imaging is a promising technique for high field systems beyond 3T. Implementation of a multi-channel coil array and parallel imaging can allow at least a 2-fold reduction in scan time without compromising the contrast between veins and surrounding brain tissue, which would be especially attractive at 7T where long TRs would prevent SWI from being routinely used in a clinical setting. The sensitivity of detecting small vessels is improved at higher field strengths.

References

[1] Haacke EM *et al* MRM 2004 52:612-8.

[2]Zwart *et al.* MRM 2002 48:1011-20.

[3] Sedlacik *et al.* 2005 Proc. 13th ISMRM.

This research was funding by grants LSIT-01-10107 and R01 CA11017