High Spatiotemporal Resolution Whole Brain Susceptibility Weighted Imaging Using Parallel Imaging

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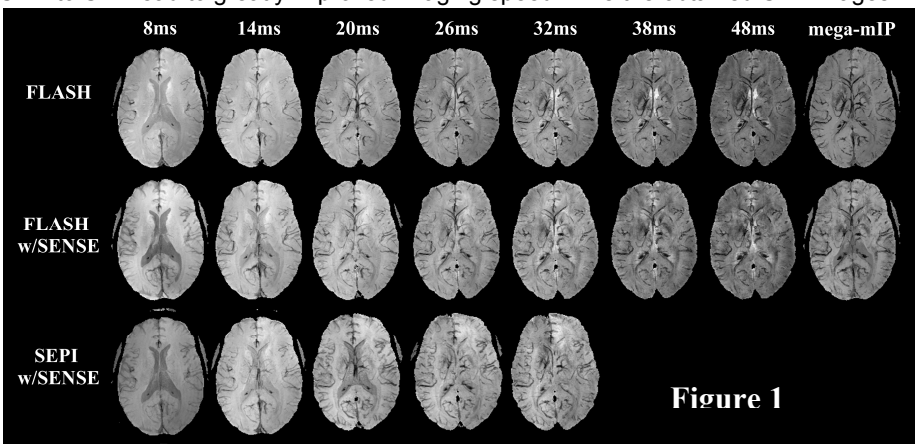
Introduction: Susceptibility-weighted imaging (SWI) is a newly developed approach to enhance contrast between tissues with different magnetic susceptibilities [1]. SWI takes advantage of the high sensitivity of NMR phase images to tissue susceptibility differences, and enhances image contrast in magnitude images using NMR phase images as masks. In addition to its initial application for imaging veins [2], SWI has been explored to improve the diagnosis of neurological trauma, brain neoplasms, and neurovascular diseases because of its ability to reveal vascular abnormalities and microbleeds (3). It also has been demonstrated as a promising tool for imaging iron stores in the brain (4) which has found novel application in multiple sclerosis (5, 6).

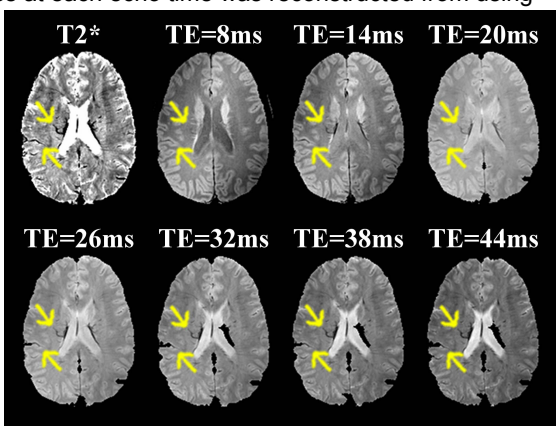
In spite of the great potentials of SWI, a major limitation exists with the current practice in SWI that is the very long imaging time arising from the exclusive use of conventional 3D FLASH sequences. Typical imaging time of 5-10 minutes covers only a small volume of the brain. Long imaging time makes the images highly vulnerable to motion artifacts, especially for patient scanning. To overcome this problem, segmented EPI (SEPI) has been proposed to improve the temporal resolution of SWI without compromising signal-to-noise ratio and imaging resolution [7].

In this study, parallel imaging was incorporated into SWI to further increase the imaging speed. The purpose of this study was to compare its performance with 3D FLASH SWI.

Materials and Method: Human brain data were acquired on a 3T Philips scanner with an eight-channel head coil (Achieva, Philips Medical Systems, Best, The Netherlands). Parallel imaging was explored for speeding up data acquisition of SWI. To compare and validate the use of various sequences using the Sensitivity Encoding (SENSE) technique for SWI, multi-echo gradient echo images collected on the same brains using a conventional 3D FLASH sequence with flow compensation were used as reference images. In comparison were images acquired using the following pulse sequences: multi-echo 3D FLASH with SENSE; single-echo 3D segmented EPI with SENSE.

Results and Conclusions: Incorporation of SENSE into SWI lead to greatly improved imaging speed while the obtained SWI images had signal-to-noise ratios similar to that obtained with conventional 3D FLASH sequence. Figure 1 gives an example comparison of SWI (in the form of minimum intensity projection or mIP images to highlight susceptibility effects, and all the images had 1mm^3 isotropic voxels) obtained with a conventional 3D FLASH sequence (TR = 66 ms, TE = 8, 14, 20, 26, 32, 38, and 44ms, 75% partial-k, TA = 6'54" for 64 slices), a 3D FLASH with SENSE (with an acceleration factor of 3, TR = 66ms, TE = 8, 14, 20, 26, 32, 38, and 44ms, 75% partial-k, TA = 6'25" for 180 slices), and 3D SEPI with SENSE (with an acceleration factor of 3, TR=66ms, 75% partial-k, TE/TA = 8ms/2'47", 14ms/54", 20ms/23", 26ms/15", 32ms/16", corresponding EPI factor = 3, 9, 17, 23, 29, respectively). The mIP images at each echo time was reconstructed from using 15 contiguous slices of 1mm thickness. The conventional SWI that uses 3D FLASH sequence (upper panel) and 75% partial-k took nearly 7 minutes to cover 64 slices. Using SENSE with an acceleration factor of 3 (middle panel), similar acquisition time allowed for whole brain coverage (180 slices). Combination of SENSE with SEPI (lower panel) lead to sub-minute data acquisition with whole brain coverage (180 slices). The two FLASH sequences (with or without SENSE) collected 7 echoes in each sequence, while the SEPI images (with SENSE) at different echo times were acquired using single-echo SEPI sequences. An advantage of multi-echo acquisition is that a gross mIP image, dubbed mega-mIP (rightmost column), of the mIP images at individual echo times could be generated, and this allows for more comprehensive depiction of the susceptibility effects, since the susceptibility contrast depends on the angle between the susceptibility interface with the B0 field, thus is a function of the echo time. Indeed, the mIPs at individual echoes highlighted different structures, and the mega-mIPs present the most comprehensive picture of susceptibility interfaces. Another advantage of multi-echo acquisition is the ability of mapping T2*. An example is given in Fig. 2 where two veins examined showed typical T2* behavior.





In summary, SEPI and parallel imaging can be applied to speed up data acquisition of SWI. When parallel imaging is combined with SEPI, sub-minute SWI with full brain coverage can be achieved, which greatly helps to improve the clinical applicability of SWI.

References: 1. EM Haacke, et al., Magn Reson Med 52: 612–618 (2004). 2. JR Reichenbach, et al. NMR in Biomed. 14: 453-467 (2001). 3. V Sehgal, et al., JMRI 22:439-50 (2005). 4. EM Haacke, et al., Magn Reson Imag. 23:1–25 (2005). 5. Y Ge, et al., AJNR 28:1639–1644 (2007). 6. EM Haacke, et al., JMRI 29:537–544 (2009). 7.S Lai et al., ISMRM 2002, p. 1097.