

In Vivo Human Brain T2* mapping using 3D high resolution multiple echo susceptibility-weighted Imaging at 7.0T

Z. Zhang¹, J. H. Jensen¹, L. Tang¹, Y. Zhu¹, and Y. Ge¹

¹Department of Radiology, New York University School of Medicine, New York, NY, United States

Introduction:

Ultra-high-field strength MR (7T or above) has provided sophisticated imaging capability to improve the fundamental quantities underlying image resolution and contrast. This includes significantly increased susceptibility sensitivity to gray matter iron deposition for studies of various neurodegenerative diseases. It's a worthwhile goal to acquire T2* mapping and phase mapping with high resolution in one scan because both types of information have the potential to assess iron content. The aim of this study was, therefore, to investigate quantitative T2* measurements and phase information of in-vivo human brains using 3D multiple in-phase echo susceptibility-weighted MR Imaging (3D MIPE-SWI) at 7.0T. In addition, the feasibility of obtaining other quantitative information such as multi-echo combined SWI magnitude images, phase images, venography and tissue segmentation based on this single 3D MIPE-SWI sequence was also explored.

Method:

Four healthy volunteers (three males and one female) with a mean age of 27.5 (range: 25-29) years were consecutively enrolled in this study. All data were acquired on 7T whole-body human MR systems with a 24 channel head coil. 3D MIPE-SWI was acquired with eight in-phase echo times (TE) ranging from 6.12 to 41.82 ms and echo spacing of 5.1 ms. Other specific parameters were as follows: repetition time (TR) =60 ms; flip angle (FA) =20°; field of view =224×196mm²; matrix =448×392; full flow-compensation in three directions; in plane resolution =0.5×0.5mm²; 72 axial partitions (slices) with partial Fourier acquisition in slice and phase encoding direction; voxel size =0.5×0.5×1mm³; Magnitude and phase images from each echo of 3D MIPE-SWI were reconstructed on the MRI scanner using GRAPPA parallel imaging (iPAT factor =2). After field inhomogeneity correction and raw data filter, maps of R2* relaxation rates and T2* relaxation times were fitted by using a least squares fitting procedure from the eight magnitude images. Because of the ability of R2* maps to show iron deposition as hyperintense areas especially for gray matter (GM) and the sensitivity of T2* maps to reveal white matter (WM) pathological changes, both R2* maps and T2* maps were all generated in this study. For phase unwrapping and SWI processing, a symmetrically centered 2D Hanning low pass frequency filter (48×48) was applied using SPIN software (<http://www.mrc.wayne.edu/download.htm>). After segmenting out the skull using boundary detection algorithm, voxels corresponding to cerebrospinal fluid (CSF) can be identified using a threshold based on the first echo T1WI and R2* mapping. The mask of the remaining brain tissue voxels (without CSF and skull) was then applied to the original T2* mapping to acquire FLAIR-like T2* maps. The phase multiplied T2* maps were also generated to provide excellent tissue contrast among WM, GM and venogram. To compare the SNR and contrast to noise ratio (CNR) of magnitude and phase images between single echo SWI and the proposed MIPE-SWI technique, the combination images from all multi-echo except the first echo and the last echo images to avoid T1 effect and severe macroscopic field inhomogeneity were generated using a sum of squares algorithm. All mapping and multi-echo data combination algorithm was processed offline using in-house-written MATLAB (Mathworks, Natick, MA, USA) scripts.

Results:

High resolution T2* and R2* maps, phase images with strong contrast, and venograms can be generated from the single 3D MIPE-SWI. **Fig.1** shows that combined multi-echo (from 2nd echo to 7th echo) magnitude (A) and phase (B) images had better SNR and CNR than their single echo (TE=21.42ms) counterpart (D and E), especially for phase images (C, F are zoomed phase images from red rectangle area in B and E respectively). Small veins are better visible and less blurred in the multi-echo images than in the single echo images. The T2* map and R2* map generated from MIPE-SWI eight magnitude images are shown in **Fig.2**. FLAIR-like T2* map and phase multiplied T2* map are shown in **Fig.3**. The phase multiplied T2* map and R2* map displayed the best contrast between GM and WM. The values of T2* for GM and WM ranged on the order of 27ms. Minimum intensity projections over 4mm of the magnitude and the venogram generated from 3D MIPE-SWI are shown in **Fig.4**.

Discussion:

A methodology has been developed based on SWI that enables obtaining quantitative information of the human brain in vivo. The proposed 3D MIPE-SWI shows promise as a tool for the non-invasive measurement of brain iron load. Further studies will be required to determine the relationship between in vivo brain R2* values or phase values and brain iron concentrations measured by brain tissue histology.

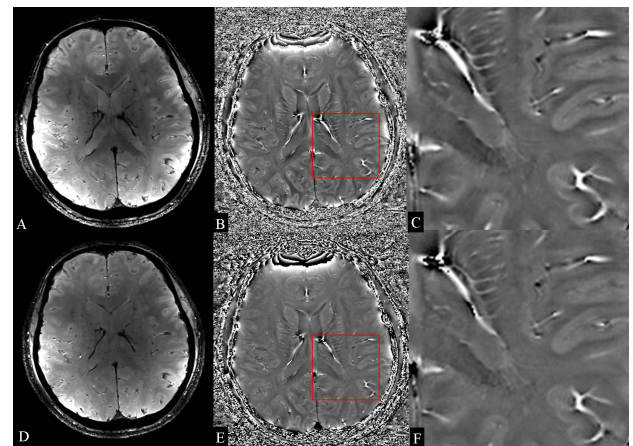


Figure 1: Combined multi-echo (from 2nd echo to 7th echo) magnitude (A) and phase (B) images had better SNR and CNR than their single echo (TE=21.42ms) counterpart (D and E), especially for phase images (C, D is zoomed phase image from red rectangle area in B and E respectively).

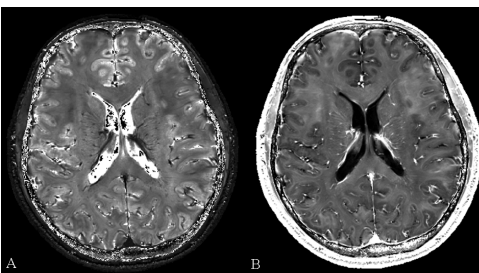


Figure 2: T2* map (A) and R2* map (B) generated from the eight magnitude images of MIPE-SWI sequence.

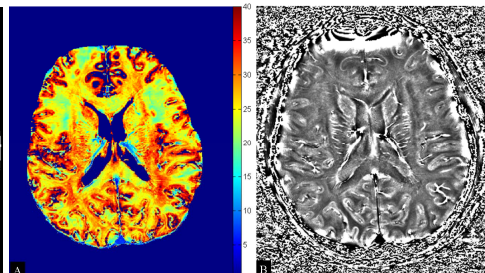


Figure 3: FLAIR-like T2* map (A) and phase multiplied T2* map (B). These images can be used to further improve contrast between WM and GM

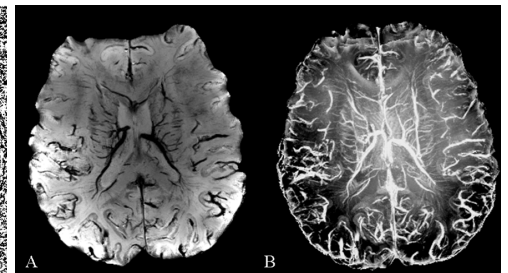


Figure 4: Minimum intensity projections over 4mm of the magnitude (A) and the venogram (B) generated by using 16 consecutive slices.

Reference:

- [1] Haacke EM, et al. J Magn Reson Imaging, 2009. 29(3): 537-544.
- [2] Haacke EM, et al. J Magn Reson Imaging, 2007. 26: 256-264.