Improving susceptibility weighted contrast using Gradient Echo Plural Contrast Imaging

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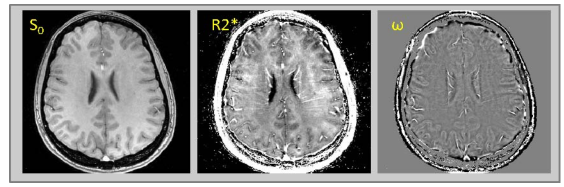
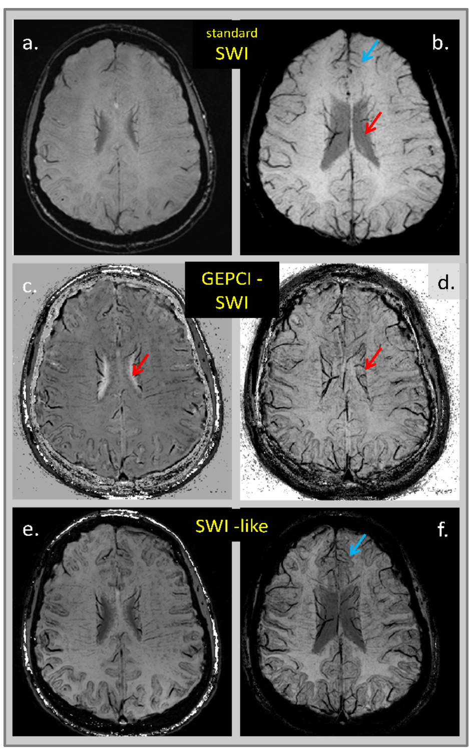
Introduction: Susceptibility weighted imaging (SWI) uses combined T2* weighted and phase images from GRE sequence to produce an enhanced contrast with sensitivity to tissue magnetic susceptibility variations from sources such as venous blood, hemorrhage, iron stores, etc (1, 2). However, SWI image is also T1 weighted (due to short TR), and is susceptible to non-uniformity of B1 field and RF coil sensitivity. A Gradient Echo Plural Contrast Imaging (GEPCI) technique (3, 4), based on acquisition of multiple gradient echoes, generates naturally co-registered images with multiple contrasts: T1 weighted, R2* = 1/T2* maps and frequency (ω) maps. Herein, we present results demonstrating capability of GEPCI technique to offer improved SWI contrast that is free of T1 weighting and RF inhomogeneities. Combining GEPCI T1 and frequency map we also generate GEPCI images with superior grey/white matter contrast.



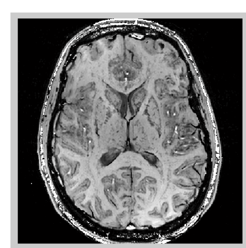
Methods and Data Analysis: Data from brain of healthy volunteers were acquired using Siemens 3T Trio MRI scanner. A 3D version of multi gradient echo sequence was used with resolution of 1x1x2 mm^3 and 11 gradient echoes (TR=50ms; delta-TE=4ms). Further effective resolution enhancement was achieved with zero-filling in k-space. Standard SWI images were also acquired with the same resolution (TR=27ms; TE=20ms). To generate GEPCI images, GRE data were fitted by the equation: $S(TE) = S_0 \cdot e^{-R2^* \cdot TE} \cdot e^{-i \cdot \omega \cdot TE + \varphi_0} \cdot F(TE)$, where *F*(*TE*) reflects signal decay due to macroscopic field inhomogeneities. This procedure produces three naturally co-registered basic GEPCI images: a quantitative R2*=1/T2* map, a frequency (ω) map, and a T1-weigted (S_0) image as shown above. Frequency maps were obtained by unwrapping and fitting 11 echoes of phase maps in the time domain, and they were subsequently high-pass filtered. To create a frequency contrast mask (FM), frequency values of less than zero were set to unity, and positive frequency values were normalized to values that ranged from 0 to 1, such that 0 corresponds to high frequency and 1 corresponds to zero frequency. GEPCI-generated **SWI-like** images that mimic the standard SWI contrast were obtained as $S_{SWI-like}(TE) = S_0 \cdot e^{-R2^* \cdot TE} \cdot FM^4$ with TE=20ms. **GEPCI-SWI** images were obtained by eliminating T1 contrast and using only FM and calculated R2* weighting at TE=20ms: $S_{GEPCI-SWI}(TE) = e^{-R2^* \cdot TE} \cdot FM^4$. Minimum intensity projection (minIP) using seven slices was also calculated for both the SWI-like and the GEPCI-SWI images. GEPCI-T1F images on the other hand were derived by using equation $S_{GEPCI-T1F} = S_0 \cdot FM^4$.

Results and Discussion: Figures on the left illustrate examples of standard SWI images (upper row), **GEPCI-SWI** images (middle row), and GEPCI-generated **SWI-like** images (bottom row). The right column is the minIP corresponding to the images in the left column. Standard SWI images (a&b) are obtained from Siemens automatic reconstruction. Images (c-f) are all derived from the same GEPCI 3D data set.



The susceptibility weighting in the **GEPCI-SWI** image, by its definition $S_{GEPCI-SWI}(TE) = e^{-R2^* \cdot TE} \cdot FM^4$ is free from T1 weighting contamination, and the RF inhomogeneity problems. One of the advantages of **GEPCI-SWI** minIP image (d) compared to the standard SWI (b) is a clearer picture of veins in the ventricle area. The origin of this advantage is the fact that CSF on the **GEPCI-SWI** images appears bright, while CSF on the standard SWI images appears dark (indicated by red arrow). Also note that the SWI-like images (e & f) derived from GEPCI showed all the venous blood vessels as the corresponding standard SWI images (a & b), with a sharper contrast (see example - blue arrow).

The GEPCI-T1F image on the right, which is also naturally co-registered with the **GEPCI-SWI** images, shows excellent grey/white matter contrast. This can potentially be used for identifying subtle cortical malformations which are sometimes associated with vascular malformations such as venous anomalies. Deep grey matter such as caudate and putamen nuclei are also clearly outlined on the GEPCI-T1F images.



Conclusion: Utilizing basic GEPCI information from T1 weighting, R2* (T2*) and frequency we can generate automatically co-registered multiple contrast MR images with high quality within one scan. In this study, we demonstrated the capability of extending GEPCI technique to produce GEPCI-SWI images that are free from T1 weighting and RF field inhomogeneities with resultant improvements in image contrast. Moreover, by combining GEPCI T1 and frequency information we demonstrate GEPCI-T1F images with superior grey/white matter contrast, thus allowing application in the evaluation of patients with subtle cortical malformations.

References: 1. Reichenbach JR, et al. Radiology 2004:272-277 (1997); 2. Haacke EM, et al. AJNR 30:19-30 (2009). 3. Yablonskiy DA. Radiology 217: 21, 2000; ISMRM (2000); 4. Bashir A and Yablonskiy DA, ISMRM (2006);