Quantitative susceptibility mapping using three dimensional segmented echo-planar imaging

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Target audience: Researchers working in Quantitative Susceptibility Mapping.

Introduction: Quantitative Susceptibility Mapping (QSM) provides unique image contrast based on differences in tissue magnetic susceptibilities. By solving the ill-posed deconvolution process, susceptibilities estimated from gradient echo phase measurements are localized and independent of B_0 orientation and TE. Typically, the acquisition time of the gradient echo (GRE) sequence ranges from 5 to 10 minutes, depending on the image resolution and filed-of-view. Three-dimensional (3D) single shot echo-planar imaging (EPI) with 1 mm isotropic resolution has been applied in functional QSM of a part of the brain at 7 T [1] and 9.4 T [2]. Further 2D single shot EPI QSM with resolution of 1.8×1.8×2 mm^3 has been demonstrated to be statistically equivalent to 3D GRE QSM at 1.5 T [3].
In this work we applied 3D segmented EPI [4] for QSM of whole brain with anisotropic resolution and whole head with isotropic resolution at 3 T.

Materials and Methods:
MRI acquisition: Phase and magnitude images were obtained from 6 volunteers using a gradient echo and two EPI acquisitions on a 3.0 T Biograph mMR (Siemens, release VB18P) after informed consent under an IRB approved protocol. The axial whole brain acquisitions were acquired with image matrix of 448 × 439 × 72, and voxel size of 0.5 × 0.5 × 2 mm^3. For GRE, TE/TR/flip angle (FA) = 25 ms/40 ms/15° with GRAPPA ×2 and imaging time of 9 min 47 sec; for EPI, 25 ms/64 ms/20° with ETL = 15 and imaging time 1 min 45 sec. The sagittal whole head acquisitions were performed with EPI only: image matrix of 352 × 340 × 288, voxel size of 0.65 × 0.65 × 0.65 mm^3, 25 ms/64 ms/12° with ETL = 15 and imaging time 4 min 45 sec.
QSM processing: Susceptibility was computed using the STI suite [10] with the following steps: (1) Laplacian-based phase unwrapping, (2) SHARP filtering with a varying spherical kernel [11], and (3) finally deconvolution is performed using an orthogonal and right triangular decomposition [8]. FLIRT was applied to coregister data from different head positions. In particular, the sagittal whole head acquisitions were re-oriented to axial orientation and re-sampled to match the whole brain acquisition. Mean susceptibility values from six regions of interest (ROIs), including red nucleus, globus pallidus, thalamus, caudate head, splenium, and centrum semiovale, were calculated and linear regression was applied to analyze the data.

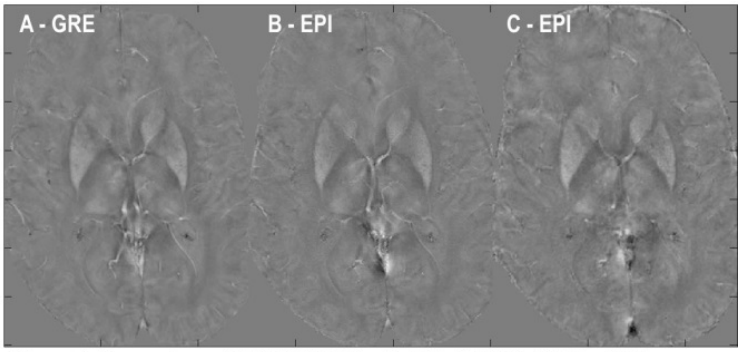

Figure 1. Comparison of GRE QSM (A) with EPI QSM (B, C). The 0.65 mm isotropic EPI (C) was re-oriented and down-sampled to match anisotropic axial acquisitions in A and B.

Results: Susceptibility maps from the GRE (Fig. 1A) and EPI QSM (Fig. 1B and 1C) show very similar contrast as compared to the average of two neutral-position acquisitions (Figure 1B). The slopes of the fitting lines using the susceptibility values from the 6 ROIs were 1.005 and 0.072, as shown in Figure 2. The corresponding correlation coefficients were 0.9539 and 0.9559.

Discussion: As demonstrated in ref 1-3, EPI QSM is statistically equivalent to GRE QSM at 1.5, 7, and 9.4 T. This work further shows that this equivalency still holds with a higher resolution at 3 T. With this equivalency, the high resolution EPI QSM can substitute GRE QSM for clinical scans.

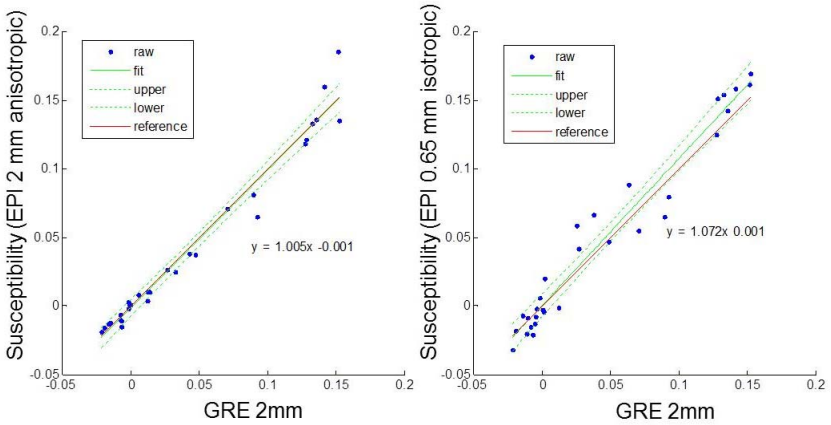

Figure 2. Slopes of susceptibility from EPI QSM are close to the reference line.

Reference: [1] Balla DZ, et al. 21st ISMRM, 2013, p0300. [2] Balla DZ, et al. 2nd Workshop MRI phase contrast & QSM, 2013, p19. [3] Sun H and Wilman AH, MRM 2014. [4] Sati P. et al. Mult Sler, 2014:17:17. [5] Susceptibility Tensor Imaging (STI) suite. http://people.duke.edu/~c1160. [6] Wu B. at el. MRM 2012;67(1):137:147.