A method for macroscopic B0 field inhomogeneity compensated SWI using 3D z-shim multi-echo GRE

Dongyoub Han1, Yoonho Nam1, Sung-Min Gho1, and Dong-Hyun Kim1
1Yonsei University, Seoul, Korea

**Purpose** Susceptibility weighted imaging (SWI) based on GRE provides enhancement of susceptibility difference which is useful for visualization of vein, micro-hemorrhage and iron deposition. However, GRE suffers from the macroscopic B0 inhomogeneity due to air/tissue boundary and this effect is shown as SNR loss both in magnitude and phase. Previously, 3D z-shim multi-echo GRE (mGRE) pulse sequence demonstrated that z-shimming can successfully recover both magnitude and phase SNR loss (Fig. 1 red arrow) due to B0 field inhomogeneity. Here, an improved algorithm for B0 field inhomogeneity compensated SWI, applicable to both magnitude and phase, is proposed using the 3D z-shim mGRE sequence.

**Methods** The 3D z-shim mGRE sequence collects both conventional echoes (odd echoes) and z-shimmed echoes (even echoes) in a single-scan. Using these echoes, both magnitude and phase data without field inhomogeneity were generated by the proposed algorithm shown in Fig. 2.

**Phase processing** To acquire B0 field inhomogeneity compensated field map, a phase combine method between conventional and z-shimmed echo was used. Background field removal method was applied to acquire local field map (LFM). Then, local phase value at specific TE (echo time) was estimated using equation described in Fig. 2 ($\gamma$: gyromagnetic ratio, $B_0$: 3 [T]). This local phase avoids wrapping artifact in SWI process (Fig. 3 phase mask).

**Magnitude processing** The field map obtained by the previous process is not only useful for acquiring accurate local field information but also for $R_2^*$ fitting. This is because magnitude loss due to B0 field inhomogeneity can be modeled as a function of the field inhomogeneity (e.g. voxel spread function (VSF) method). The VSF method which is appropriate for 3D mGRE was modified to incorporate the z-shimmed echo signals and was applied for $R_2^*$ fitting to acquire $M_0$ and $R_2^*$ values. Afterwards, macroscopic B0 field inhomogeneity compensated magnitude was estimated using a mono-exponential model as shown in Fig. 2.

**SWI processing** Using the above field inhomogeneity corrected magnitude and phase values, complex data at TE=22 ms was generated to apply to the SWI process. High pass homodyne filter was applied to the corrected complex data and a phase mask was generated to eliminate the remaining low frequency term. Finally, an SWI image was generated by multiplying B0 field inhomogeneity compensated magnitude with the fourth power of phase mask. A mIP (minimum intensity projection) was performed over 4 adjacent slices (12mm). Comparison with conventional SWI was done from data at the same echo time.

In vivo experiment was performed with two healthy volunteers. Data were collected in 3T (Siemens Tim Trio) scanner with 40 slices/slab, voxel size: 1x1x3 mm3, TR: 42.5 ms, 1st TE: 3.96 ms, ES: 3 ms, FA: 18°, BW for conventional echo: 240 Hz/Px, BW for z-shimmed echo: 1021 Hz/Px. A total 11 echoes were acquired (6 conventional echoes and 5 z-shimmed echoes).

**Results** Void regions due to field inhomogeneity in conventional magnitude images are recovered in the proposed magnitude images (Fig. 3). Furthermore, wrapping artifacts disappear with the proposed phase mask (Fig. 3). Improvements in the SWI and mIP are also shown in Fig. 4. Veins not shown in conventional images and void region (white arrows) appear in the proposed method results. Furthermore, dark artifacts near the boundary of brain in conventional images also disappear in the proposed method.

**Discussion** The $R_2^*$ fitting process based on multi-echo inherently has a noise reduction effect. Thus, the estimated magnitude image has higher SNR than magnitude from a conventional echo.

**Conclusion** We have presented a macroscopic B0 field inhomogeneity compensated SWI method by correcting both magnitude and phase using 3D z-shim multi-echo GRE sequence. This method would be useful for detecting hemorrhage located in frontal and temporal lobe.