Dual echo susceptibility weighted imaging (SWI) : Reducing the error in making phase mask.

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Introduction:

A high pass filter is applied to eliminate phase wrapping in the image processing of susceptibility weighted imaging (SWI). However, insufficient removal of phase wrapping might occur with the known filter technique when there is a steep phase change. This process also has the possibility of changing positive phase values to negative phase values, and might make another artifact on the phase mask consequently. In this study, we show an example of phase error with the known filter technique, and propose a novel technique with the combination of dual-echo image acquisition.

Material and Methods:

Imaging techniques: All MRI was performed using a 1.5-T MR scanner (Gyroscan ACS-NT 1.5T R6; Philips Medical Systems) with a birdcage head coil. 3D Fast field echo (FFE) pulse sequence (TR = 50 ms, FA = 20, degrees, NSA = 1, number of slice = 50, voxel size = 1 × 1 × 1mm) with the dual-echo technique was used for all examinations.

Data analysis: Real and imaginary data were obtained at 1st and 2nd TE. These 4 images at every slice positions were processed on a personal computer (Dimension 9100; Dell). In the single-echo SWI, we used only 2nd TE data and applied a common high pass filter [1]. In the dual-echo SWI, we calculated the phase difference caused in TE interval by complex dividing the phase of 2nd TE with the phase of 1st TE. Then this phase difference converted to the time-dependent component at the time of 2nd TE, and subtracted from the phase of 2nd TE. Because this remaining phase has only time-invariant component, severe phase wrapping tends not to appear. We used this time-invariant phase for making a phase mask.

Phantom study: We evaluated phase change of the $CuSO_4$-doped solution with different concentrations (1, 5, 10, 20, 50) and TEs (10, 20, 30, 40ms at 2nd TE, TE interval was fixed at 5 ms). High pass filtered phase with single-echo and time-invariant phase with dual-echo were evaluated.

Human study: We validated dual-echo techniques in the examination of a volunteer. A 3D-FFE acquisition was performed with 1st TE / 2nd TE = 30 / 40ms. Because time-invariant phase still include background field inhomogeneities, we applied a weak high pass filter to the time-invariant phase. The Hanning filter size 16 × 16 was used in the dual-echo SWI with 512 matirx imaging.

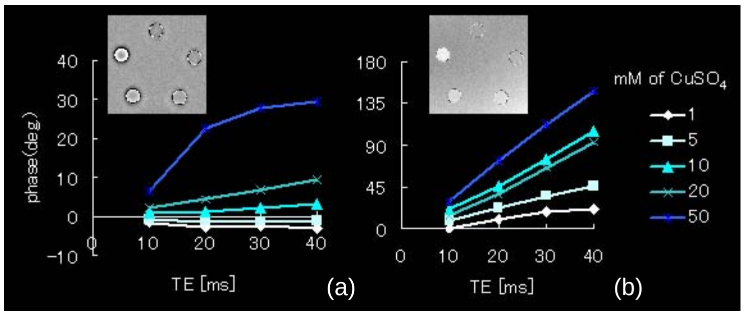

Figure 1 (a) High pass filtered phase with single-echo technique. (b) Time-invariant phase with dual-echo technique. The linearity between phase and TE is lost in case of high concentration of $CuSO_4$ seen in (a).

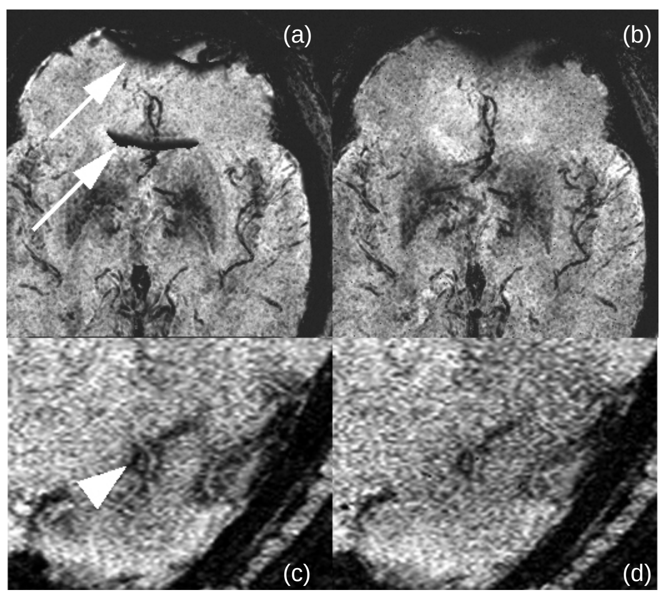

Figure 2 MinIP and one of their source images. (a) and (c) are single-echo technique. (b) and (d) are dual-echo technique. Insufficient removal of phase wrapping (arrows) and edge enhancement of small artery (arrowhead) were seen in the single-echo technique. These artifacts are improved with the dual echo technique.

Results and discussion:

Figure 1 shows the relationship between TE and phase of each $CuSO_4$-doped solution. The phase was not linearly proportional to the TE at high concentration with single-echo technique. An edge enhancement effect of filtering seems to be a reason of this unconformity. Figure 2 shows results of human study. Phase wrapping remains with single-echo SWI (arrows) and a thin artery is prominent (arrowhead). These artifacts were not seen with the dual-echo SWI.

Reference:

[1] Wang Y, et al. J Magn Reson Imaging 2000; 12: 661-70