Multi-layer appearance of abscess capsule on post-Gd SWI images: effects of filtering and phase mask

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Introduction

Susceptibility-weighted imaging (SWI) is a novel magnetic resonance (MR) technique that exploits the magnetic susceptibility differences of various tissues, such as venous structure and iron deposition [1]. SWI consists of a number of post-processing steps using both magnitude and phase images obtained from a high-resolution, three-dimensional (3D) fully velocity-compensated gradient echo sequence [2]. A corrected phase mask is created from the high-pass-filtered phase images, and multiplied with the magnitude images to produce SWI images to increase the conspicuity of small veins and other sources of susceptibility effects. These processing steps could affect the image appearance in unexpected manners. When SWI was applied to patients with abscess, we found that, compared with homogeneous rim-enhancement on post-contrast magnitude images (Fig.1a) [3], the capsular portion of pyogenic brain abscess on post-contrast SWI images showed a multi-layer appearance (hollow arrow in Fig.1b). In this work, in order to clarify whether this multi-layer characteristic is physiological or technical in it origin, we investigate the causes of this multi-layer appearance, and use a theoretical model to simulate the multi-layer appearance upon the use of different SWI processing parameters.

Materials and methods

In the presence of paramagnetic substances such as Gd at the rim of abscess capsule, phase shifts are induced around this rim due to susceptibility effects. The Gd within the abscess capsule behaves like a paramagnetic spherical shell with finite capsular thickness, generating field perturbation given by $\Delta B = (3\cos^2\theta - 1)\Delta\chi\, B_0 \cdot R_i^3 / 3r^3$ within the capsule and $(3\cos^2\theta - 1)\Delta\chi\, B_0 \cdot (R_i^3 - R_o^3)/3r^3$ outside the abscess, respectively [4]. The effects of this field distribution on the resulting SWI images were computed on a mathematical phantom containing a paramagnetic spherical shell. Five patients with brain abscess were scanned on a 1.5T scanner (Signa, GE) using a 3D SPGR acquisition (TE/TR 39/50ms, α 40°, FOV 220×220mm, thickness 2.5mm, matrix 288 × 256) to simultaneously reconstruct the magnitude and phase images for SWI post-processing. For both the mathematical phantom and human imaging data, the effects of different filter sizes and mask times were examined by varying the filter matrix size (8 × 8, 16 × 16, 32 × 32, 48 × 48, and 64 × 64) to create the corrected phase masks, and performed 1, 2, 3, 4, and 5 times of multiplication on the magnitude images with the phase mask.

Results

Figs.1c & 1d show the simulated T1-weighted image and SWI of the spherical shell phantom, respectively (8x8 filter and 5 mask times). The yellow curves in Figs.1a & 1c correspond to the phase profiles of brain abscess and simulated images along the red dotted line within the white margins, showing qualitative similarity. The change of signal profiles (corresponding to yellow phase profile) at different filter sizes applied on SWI images is shown in Fig.2a (phase mask multiplied 5 times). Compared with the black line representing original signal profile, all color lines exhibit reduced signal intensity near the center of the abscess capsule after filtering, consistent with the clinical observations. Figs.2b & 2c show the corrected phase profiles with different filter sizes for the human brain image and for the phantom, respectively. Increase in the number of phase mask multiplication from 1 to 5 demonstrates similar but somewhat milder effects (not shown).

Discussion & Conclusion

The susceptibility-induced phase shifts of the abscess capsule consist of both high spatial frequency components at the capsular boundary and low spatial frequency components within the capsule. The high-pass filter used in SWI purposely removes low spatial frequency background field variations to create the corrected phase mask. When using a stronger filter (smaller filter matrix size), low spatial frequency phase variations within the abscess capsule are reduced and high spatial frequency variations in the phase shifts become relatively magnified (Figs.2b & 2c), resulting in the multi-layer appearance shown in Fig.1b. The phase mask multiplication time is also a factor causing multi-layer appearance of abscess capsule on post-Gd SWI, but we found that the filter matrix size seems to predominantly decide the image behavior. In conclusion, the multi-layer appearance of abscess capsule on post-Gd SWI images can be caused by the post-processing procedure as verified from phantom simulations, and hence does not necessarily reflect physiological alterations. Cautions in the interpretations of clinical post-Gd SWI images are therefore warranted.

References

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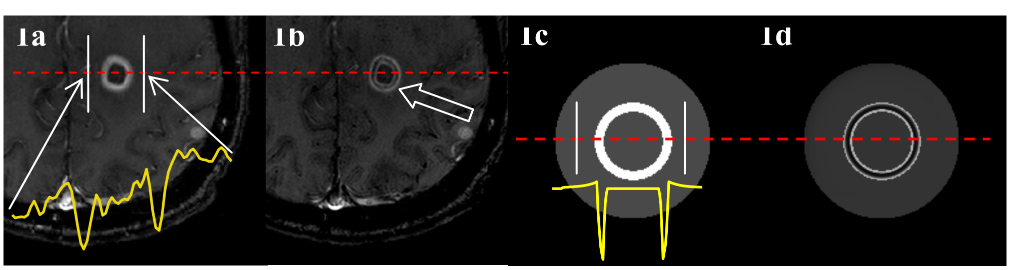

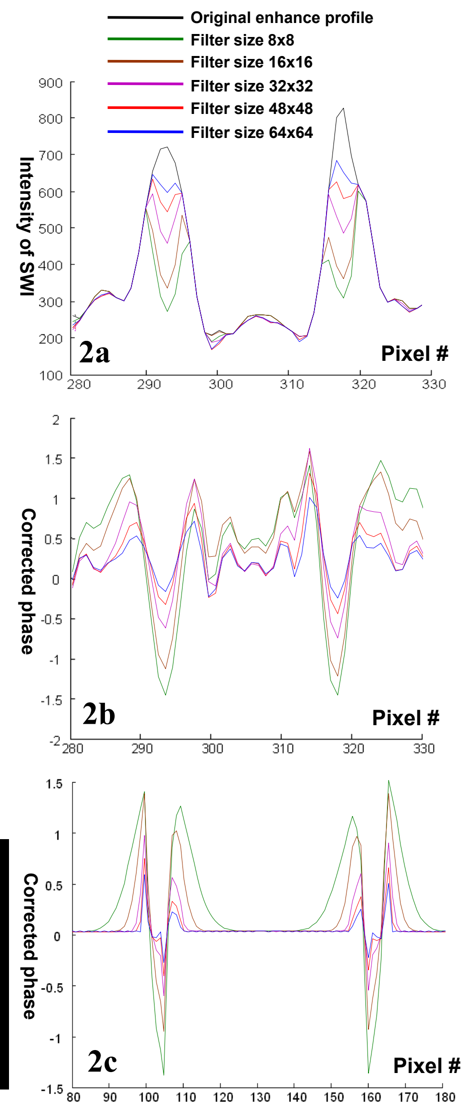

Fig.1. Post-Gd magnitude image (a) and the image with SWI post-processing (b), showing multi-layer appearance of the abscess capsule in (b) (hollow arrow; thin dark layer within the enhanced rim). A mathematical phantom simulating the rim structure without (c) and with (d) SWI post-processing show similar results from the theoretical calculations. **Fig.2.** The SWI signal profile (a) and the phase profile from the brain image (b), as well as the phase profile calculated from the phantom (c) all show increased multi-layer behavior as the filter matrix size becomes smaller.