Phase susceptibility-weighted imaging of SPIO nanoparticles

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Introduction

Molecular imaging of superparamagnetic iron oxide nanoparticles (SPIONs) is an effective method for cell tracking using magnetic resonance imaging (MRI). Ferumoxide is a commonly used SPION that has been shown to incorporate easily into cells and can be imaged using a variety of MRI techniques *(1)*. A new technique for susceptibility-weighted imaging (SWI) of SPIONs using phase-based SWI is presented. To determine whether this method is appropriate for SPION imaging, sensitivity and SNR of magnitude-based and phase-based SWI were compared.

Materials and methods

GRE-EPI magnitude and phase images of nine agar-filled conical tubes serially-diluted with ferumoxide (Feridex IV®, Berlex Laboratories, Inc., Wayne, NJ), and one control agar phantom were acquired on a Philips 3.0 Tesla system (Philips Medical Systems, Best, NL) with a Philips head SENSE coil. A series of images was acquired with multiple TEs from 5.4 – 29.4 ms in 2 ms increments. Each image was acquired with TR 150 ms, FOV 200 mm, matrix 204x256, and slice thickness 3.0 mm. R_2* mapping of the magnitude data was calculated using a linearized two-point fit. Phase shift ($\Delta\phi$) SWI maps were calculated using a phase subtraction algorithm similar to that in *(2)*. For our purpose, images were ordered according to the TE of image acquisition, and adjacent images were subtracted in pairs. The subtracted values were then integrated to calculate the total phase difference between two greater difference TE images. After processing, an ROI was placed to measure the mean and standard deviation of the phantoms, from which the SNR was calculated. The mean was calibrated by the control phantom to remove any susceptibility effects of agar.

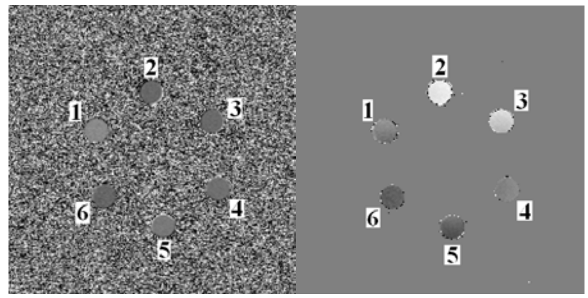

Figure 1. *R_2* (a) and $\Delta\phi$ (b) susceptibility-weighted images of 5 0.08% agar phantoms serially-diluted with iron (vials 1-5, in decreasing order) and one 0.08% agar phantom (vial 6). The images were calculated between the lowest two TE images for both methods.*

Results

Processed R_2* and $\Delta\phi$ images between 5.4 and 7.4 ms TE images of the five lowest concentrations and control data is shown (Figure 1). Vial 1 appears to produce a saturated signal even at the lowest TE. Analysis of the images (Figure 2) supports this and reveals that vial 5 is not statistically different from agar. Thus, only vials 2-4 have reliable SWI effects (solid lines). The reliable vials show a non-linear relationship between R_2* and iron concentration, while $\Delta\phi$ appears linear to iron concentration. The SNR decreases with concentration for both methods, however the SNR for the $\Delta\phi$ method is 3.2-80 times that of the R_2* method in vials 2-4. These relationships to concentration and the SNR benefit of the $\Delta\phi$ method are consistent with results reported for gadolinium *(3,4)*.

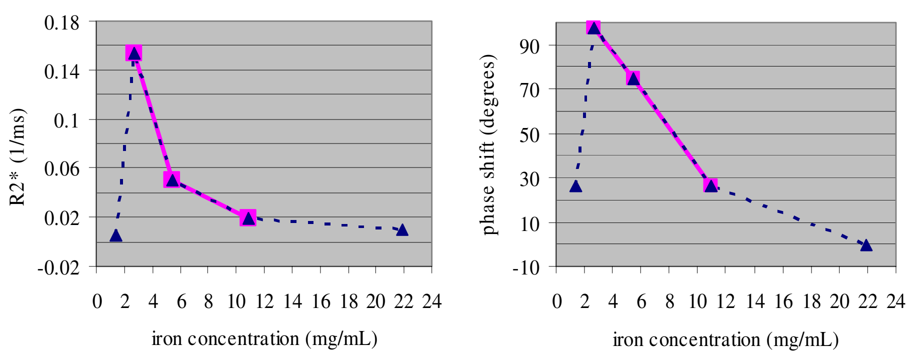

Figure 2. *R_2* (a) and $\Delta\phi$ (b) versus iron concentration. On both plots, the signals are not reliable due to saturation at the highest concentration and low sensitivity at the lowest concentration. The reliable portion for the curve (solid line) for R_2* appears non-linear while $\Delta\phi$ appears linear to iron concentration.*

Discussion

Phase-based SWI of SPION particles appears to be linear to concentration of iron particles and has higher SNR than magnitude-based SWI methods. More studies need to be done to determine the sensitivity limits of phase-based methods.

References:

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