Towards Microcalcifcation Detection Using Susceptibility Weighted Phase Imaging: Simulations and Phantom Experiments

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INTRODUCTION

The presence of calcium deposits in the breast can be an indicator of malignancy, so the ability to detect such abnormalities by MRI would be significant. Calcium deposits have a different magnetic susceptibility from surrounding tissues that can in principle be observed using susceptibility weighted imaging (SWI) [1]. Here we perform simulations and phantom experiments to determine whether SWI can be used to detect calcifications in practice.

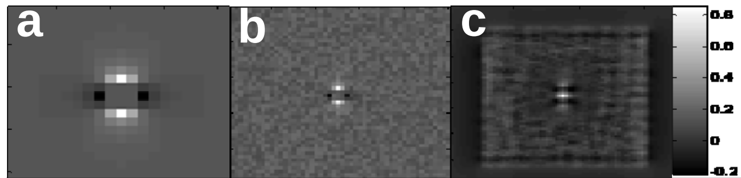

Fig. 1. a) Magnetic shift simulation of a 1 mm spherical calcification; this provides the "template". b) template + 20% noise; this provides the "data". c) Cross correlation matrix obtained from the template and data showing the ability of the template to locate a similar phase signature within an image.

METHODS

Simulations The MR signal phase variations caused by a spherical calcium-like object immersed in a homogeneous media was simulated in 2D using the method described in (4). The simulations incorporate phase shift as a function of the static field ($\boldsymbol{B_0}$) strength and orientation, echo time (*TE)*, and the geometry and susceptibility characteristics of the perturbing material. Calculation of magnetic susceptibility differences is performed for each voxel in a "slice" to generate phase images. The simulations employed the following MRI parameters: voxel size = $(300\ \mu m)^3$, sphere centered within the voxel, $\boldsymbol{B_0}$ = 4.7T, and *TE* = 0.3 ms and the resulting data can be seen in Fig. 1a. This "template" was then added to noise to yield an image with SNR=5 (Fig. 1b); this resulting image then simulates experimental "data". We then aim to asses the ability of the template to locate a susceptibility induced signature (i.e., a phase pattern) within an experimentally measured data set by using a 2D cross correlation with the predicted pattern.

Phantom studies. Phantoms were constructed with 1.0 mm barosilicate spheres immersed in Agarose gel. MRI employed a 4.7T Varian scanner to obtain 3D gradient echo images with TR\TE\α= 10.5ms\5ms\15^o, with an acquisition matrix of 256×128×128 over a 80×40×40 FOV. Figure 2 shows the MRI magnitude (panel a) and phase image (b) obtained from the phantom. A phase pattern template (Fig. 1a) was then used to identify whether the phase pattern of small irregularities are present within the phantom phase image (Fig. 2b).

Analysis

The goal is to locate, within an experimental data set, a characteristic phase response pattern induced by a calcium-like sphere. For the simulation, this amounts to simply applying a 2D cross-correlation (the 'normxcorr2' function with Matlab (Mathworks; Natick, Massachusetts) between the template and the data image. The resulting cross correlation matrix will have high values where the template and the target pattern in the image are similar. For the phantom studies, before the cross-correlation is performed, we first correct the phase jumps for phase values outside $[-\pi, \pi]$ using the technique provided by (5); an example can be seen in Fig. 2c.

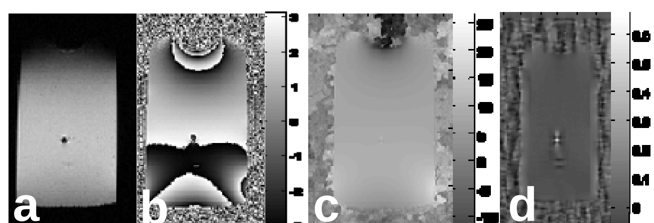

Fig. 2. The experimental analogues of Fig. 1. a) Spin density-weighted 3D GRE image. b) Raw phase image. c) Phase image after unwrapping *via* the Goldstein method (5) d) Cross correlation matrix obtained using the Fig. 1a template.

RESULTS

Fig. 1c depicts the cross-correlation matrix obtained for the simulation studies. It shows a high correlation coefficient (~0.8) near the center of the field of view (FOV) where the calcification is present. As the SNR of this data set is quite low (SNR=5), this offers promise for the technique. Fig. 2d depicts the experimental analogue displaying a correlation coefficient of ~0.65 in the center of the FOV.

DISCUSSION and CONCLUSION

We have introduced a simple technique to locate a susceptibility induced signature within a data set by computing the cross-correlation between a template and the target image. The preliminary efforts indicate that there is some merit to the approach. Ongoing and future efforts include exploring the ability of the method to find phase signatures with different levels of background noise and structure. Additionally, we are constructing a library of more realistic templates (various sizes, shapes, etc. of calcifications) to increase the applicability of the method.

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