Identifying Breast Calcification by Using Susceptibility Weighted Imaging: Optimizing Parameters for Detection of Calcifications at 3T

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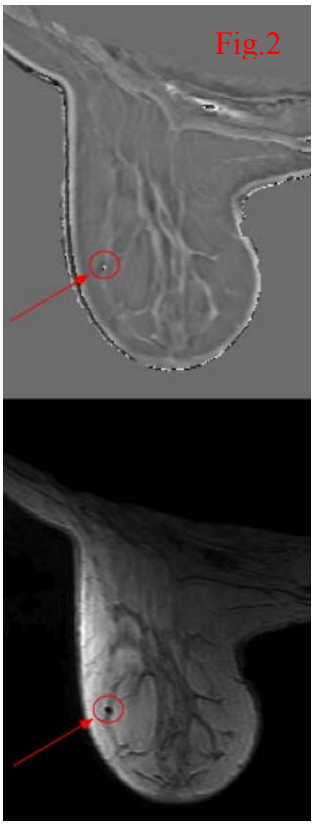
Introduction:

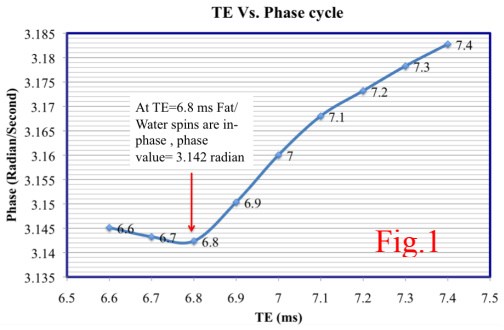
A significant weakness of current clinical breast magnetic resonance imaging (MRI) is that detection and characterization of calcification has not been possible. While almost all invasive breast cancers will show enhancement with dynamic contrast enhanced (DCE) MRI, a substantial number of cases of pre-invasive cancer (ductal carcinoma *in situ*, DCIS) may not enhance with this technique. In fact between 10% and 22% [1] of DCIS cases diagnosed with mammography are not diagnosed with MRI because of lack of suspicious enhancement. In conventional MRI, macroscopic calcification will reduce signal relative to the surrounding tissue. However, microcalcification will either insignificantly reduce MRI signal or not change signal at all, and will not be visible [2]. However, it has been recognized that using corrected positive phase images helps visualization tissue calcification precipitate [3]. We have optimized corrected phase images acquired at 3T with a dedicated breast coil to detect breast microcalcification. Corrected phase images demonstrating calcifications correlate well with x-ray mammography.

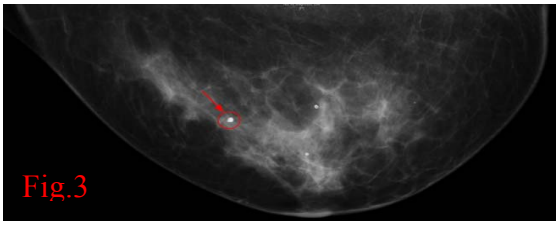


$$CNR_{phase} = \frac{\Delta\varphi}{\sigma_{phase}} = \frac{\gamma \cdot \Delta B \cdot TE \cdot Signal_{magnitude}}{\sigma_{magnitude}} \sim \frac{\gamma \cdot \Delta B \cdot TE \cdot \Theta \cdot e^{-TE/T2^*}}{\delta_{magnitude}} \quad \textbf{Eqn 1.}$$

$$CNR_{phase} \sim TE \cdot e^{-TE/T2^*} \quad \textbf{Eqn 2.}$$

$$\frac{dCNR}{TE} = \left(e^{-TE/T2^*} - \frac{1}{T2^*} \cdot TE \cdot e^{-TE/T2^*} \right) = 0 \rightarrow TE = T2^* \quad \textbf{Eqn 3.}$$





Materials and Methods:

Scanning was done using a GE 3T Signa HD MRI (GE Healthcare, Milwaukee, WI) and a Sentinelle 8 channel phased array breast imaging system (Toronto, Canada). SWI is a 3D fast gradient echo sequence with flow compensation in all three orthogonal directions (FA=15°, BW= 400 Hz/pixel. 512 × 512 matrix size). We optimized this sequence, balancing resolution, imaging time and signal-to-noise ratio (SNR). In order to make the Ca^{2+} [diamagnetic] dipole effect minimal for small microcalcifications, isotropic voxels are required. The TR was minimized (TR=60 ms) and subsequently TE needed optimization to maximize phase contrast, according to **Eqn.1**, where the parameter Θ includes the T1, spin density, and flip angle dependent part of the signal. From **Eqn.1** in order to optimize the CNR between two tissues with small T2* difference (here the result of Ca^{2+} presence i.e., T2* and T2*+δ), CNR_{phase} can be estimated by **Eqn.2**. Optimization of CNR with respect to TE was done by solving the ODE (**Eqn.3**) giving a TE = 17.8 ms. The long echo time of ~17.8 ms (to match T2*, as seen in **Eqn.3**) yielded significant aliasing in the phase images [4] caused by ΔB. This resulted in reduced remaining signal from local calcification. In addition, the 3D gradient echo needs to be in-phase to minimize boundary effects. To achieve in-phase scanning the TE was calculated experimentally [**Fig.1**]. However, to balance CNR and aliasing, and be in-phase, $TE_{inphase}$= 6.8ms was used. Based on **Eqn.2** this resulted in only 23% reduction in CNR. A high-pass filter was applied to remove low-spatial frequency components, caused by background field effects. Our optimized SWI protocol was tested on a 48yr old woman with mammography confirmed benign microcalcification.

Results and Discussion:

The presence of calcification was evident in both SWI corrected phase **[Fig.2, top]** and magnitude **[Fig.2, bottom]** images. Calcification on magnitude images presented as hypointense foci. The phase images showed the calcification as hyperintense foci that correlated with calcifications demonstrated by mammography **[Fig.3]**. The corrected phase contrast between breast and calcification lesion (surrounding tissue) using in-phase TE=6.8 ms (~ half of $T2^*$) was found to be 78% of the peak contrast compared to that if a longer echo time (when TE=T2*) is used.

References:

[1] Gilles, *et al.* (1995) Radiology, 196:415-419. **[2]** Oot, *et al.* (1986) AJNR 7:801-809. **[3]** Wu, *et al.* (2008) JMRI 29:177–182. **[4]** Haacke, *et al.*, (1999) Magnetic Resonance Imaging: Physical Principles and Sequence Design, Wiley, New York.