In-vivo Breast Microcalcification Detection via Susceptibility Weighted Imaging at 7T

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INTRODUCTION: Clinical breast MRI, as opposed to mammography, does not involve ionizing radiation and is sensitive in early detection of invasive cancers [1]; however, pre-invasive cancer – *ductal carcinoma in situ* (DCIS) may frequently be missed by the standard dynamic contrast-enhanced (DCE) MRI [2]. DCIS originates from the lactiferous ducts and 30% to 50% of patients who have DCIS will develop invasive ductal carcinoma over a 10-year period [3]. DCIS has been shown to strongly associate with particular distributions and patterns of microcalcifications. A microcalcification-mapping via susceptibility weighted imaging (SWI) [4] has been proposed as a non-invasive alternative to the current gold standard of mammography for early detection of certain DCIS-associated breast microcalcifications (based on their diamagnetic properties), providing better localization and 3D morphology without ionizing radiation. Critically, SWI may be of particular use in cases of dense breast in younger females, which are often very difficult to investigate via mammography and has the potential to address the significant concerns about carcinogenicity and repetitive use of radiation in younger women and especially in women with BRCA 1 mutation. An isotropic resolution of 0.4 mm or better has been stated as being highly preferable for microcalcification detection via MR SWI [4]; however, this resolution is not currently feasible on clinical 1.5T and 3T MR systems due to the long acquisition time required. Ultra high field (7T) offers tremendous advantage by providing higher susceptibility effects [5] and a gain in signal-to-noise ratio (SNR). This work demonstrates ultra-high resolution 7T SWI *in vivo* for calcification detection and compares results with mammography findings.

METHODS: Human experiments were performed using a protocol approved by the local IRB. Data were acquired on a whole-body 7T scanner (Achieva, Philips Medical Systems, Cleveland, OH, USA) using unilateral Forced Current Excitation breast quadrature coil [6] and a 16-channel breast receive array insert [7]. T2*-weighted magnitude and phase images of the breast were obtained using a flow compensated ultra-high resolution (0.35mm isotropic) 3D axial gradient-echo sequence with TE 7ms, TR 16ms, flip angle 10 degrees, SENSE 2x2 (RLxFH), with ROSE excitation [8] and FOV 128x170x140 (APxRLxFH) and total scan time of 7.5 min. Phase images were first processed using Laplacian unwrapping [9] and then filtered using a homodyne filter of 25% of the image size. These phase images (Figure 1) provide a contrast that could enable the identification and characterization of susceptibility sources such as microcalcifications. The susceptibility distribution was visually compared with mammography results. A high-resolution THRIVE scan provided additional breast morphological information.

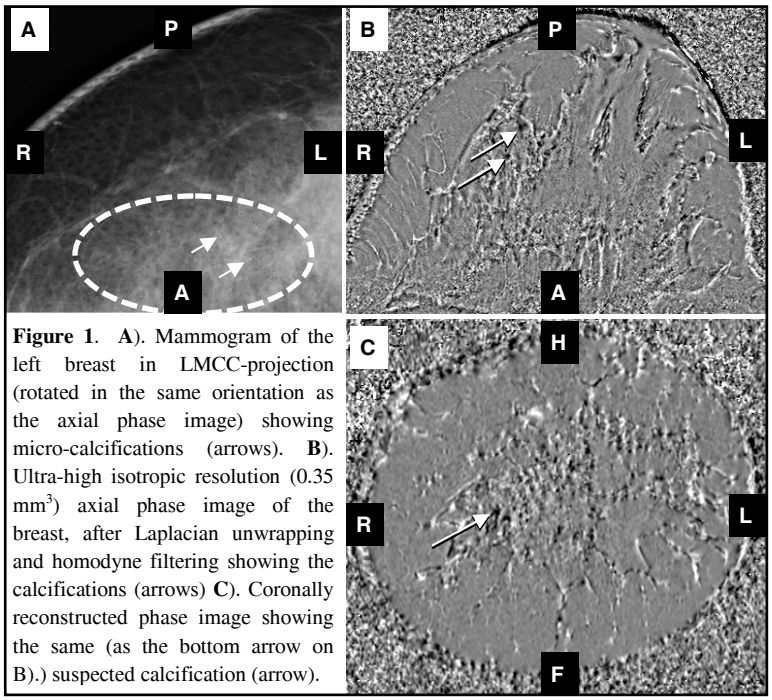

Figure 1. **A**). Mammogram of the left breast in LMCC-projection (rotated in the same orientation as the axial phase image) showing micro-calcifications (arrows). **B**). Ultra-high isotropic resolution (0.35 mm^3) axial phase image of the breast, after Laplacian unwrapping and homodyne filtering showing the calcifications (arrows) **C**). Coronally reconstructed phase image showing the same (as the bottom arrow on B).) suspected calcification (arrow).

RESULTS AND DISCUSSION: Figure 1 shows a comparison of the magnified mammogram image with the corresponding SWI phase images of a subject with pathologically-confirmed atypical ductal hyperplasia and coarse microcalcifications. This example demonstrates that SWI at 7T is clearly capable of detecting microcalcifications. Intensity changes caused by calcifications on the magnitude images are rather small but the processed phase map produced by the analysis of phase variations presents diagnostic value. Formations of sub-millimeter size on the mammogram are visible on the Laplacian-unwrapped and homodyne-filtered images (arrows). Susceptibility sources show characteristic blooming dipolar pattern (see coronal plane). Additionally, an agar phantom with embedded small particles of calcium hydroxyapatite (to simulate calcifications [5]) was scanned on both 7T and helical CT to verify consistency of detection (data not shown). In the future we plan to obtain quantitative susceptibility maps, using a L1 or L2-regularized quantitative susceptibility mapping (QSM) algorithm [10] with optimal regularization on a subject-by-subject basis using a noise power criterion [11]. The high resolution T1w 3D THRIVE (not shown) provides detailed information of breast duct locations that can be correlated with the susceptibility findings.

CONCLUSIONS: Ultra high resolution 7T SWI for breast calcification detection *in vivo* has been demonstrated. As a future work we plan to correlate co-localization of microcalcification patterns from the SWI images with ductal patterns from T1-weighted images in a population of women with DCIS. This new contrast mechanism has the potential to improve sensitivity and specificity of detection and ultimately improve diagnosis.

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