A 3D PR Sequence (PR-TRICKS) for Dynamic Contrast Enhanced (DCE) Imaging of the Breast

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INTRODUCTION

Breast MRI has been shown to have high sensitivity but variable specificity for the detection of breast cancer [1,2]. The temporal analysis of dynamic contrast enhanced images has shown promise as method to characterize benign and malignant lesions in breast MRI [3]. While high spatial resolution is needed to localize lesions using DCE-MRI, high temporal resolution is also needed to more accurately depict the contrast uptake or "wash in" by the tumor [4]. Several non-Cartesian MRI acquisition sequences have been proposed to improve the spatial and temporal resolution of DCE breast MRI including spiral [5] and projection acquisition [6] methods. The PR-TRICKS method, which uses undersampled projection acquisition (PR) in-plane and TRICKS [7] in the slice direction, has been shown to demonstrate contrast uptake dynamics in MR angiographic applications [8]. The purpose of this work is to apply a modified version of the PR-TRICKS acquisition to perform DCE-MRI of the breast at high temporal and spatial resolution to improve the characterization of breast lesions.

MATERIALS AND METHODS

The modified version of the PR-TRICKS sequence consists of 3 phases: A mask phase in which all projection angles and all Fourier views are acquired, a dynamic phase during contrast wash-in which all projection angles are acquired but only the center-most k-space views are acquired every 4-7 s, and a washout phase in which the volume was acquired at full resolution every 8-14 s (Fig.1a). Projection angles are dithered to so that under-sampling is reduced for larger temporal apertures.

Phantom and volunteer experiments were performed on a 1.5 T scanner (Signa LX; GE Medical Systems, Milwaukee, WI) using a commercial breast coil (Medical Advances, Milwaukee WI) and an rf-spoiled GRE pulse sequence. Common parameters for these experiments: azimuthal sampling 36-72 projections, ± 64 kHz bandwidth, and 15° flip. Specific to the phantom experiments a 256×256×36 matrix was used with a 30 cm FOV yielding a 1.2×1.2×2.2 mm^3 voxel size and a TR/TE 5.3/1.1 ms. A spatial resolution phantom was combined with a flow phantom (Fig. 1b-d) to demonstrate the ability to measure contrast wash-in and out while maintaining spatial resolution. The temporal resolution of the PR-TRICKS was varied from 4-7 s during the wash-in phase and 8-12 sec during contrast wash-out. A reference curve was measured independently using a 2D GRE sequence with a 0.4 s resolution. In the volunteer studies Gadodiamide (Omniscan, Amersham Health, Princeton NJ) was injected intravenously (0.1 mmol/kg) at 3 cc/s. For the volunteer with bilateral lesions, a bilateral DCE-MRI data set was acquired using the modified PR-TRICKS at a FOV of 28 cm, 384×384×48 matrix, for a 0.7×0.7×2.2 mm^3 voxel size, TR/TE 6.9/1.2 m.s. The temporal resolution for the wash-in phase was 6 s and for wash-out was 14 s.

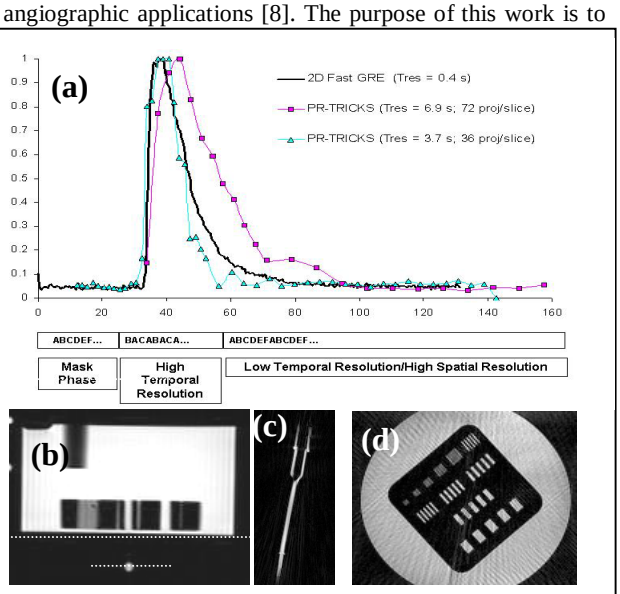

Figure 1: (a) Phantom experiment time courses measured using modified 3D PR-TRICKS. (b) phantom design showing carotid flow and resolution phantom in axial plane. (c) Carotid flow phantom and (c) resolution phantom showing in-plane resolution.

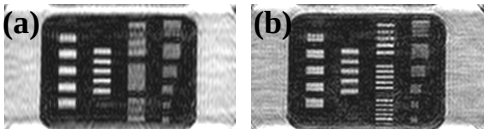

Figure 2: (a) Slice resolution for wash-in phase and (b) for wash-out phase in phantom experiment above.

RESULTS and DISCUSSION

The contrast uptake was accurately measured for both PR-TRICKS time resolutions although the wash out lagged as expected (Fig 1a). In plane resolution of 1.2 mm was maintained throughout (Fig 1d). The slice resolution varied from approximately 5 mm during the wash-in to 2.2 mm during the wash-out (Fig 2 a and b). Both the tumors were detected using the 3D PR-TRICKS. The rim-enhancing tumor in the right breast (Fig.3a, upper arrow) was diagnosed as malignant based on permeability >1.2 min^{-1} while the smaller fibroadenoma in the left breast (lower arrow) was misdiagnosed as malignant due to an early intense wash-in at 24 s post-injection, perhaps due to first-pass vascular volume. The second volunteer did not receive contrast but the in-plane resolution is demonstrated for a unilateral sagittal study (Fig 3b).

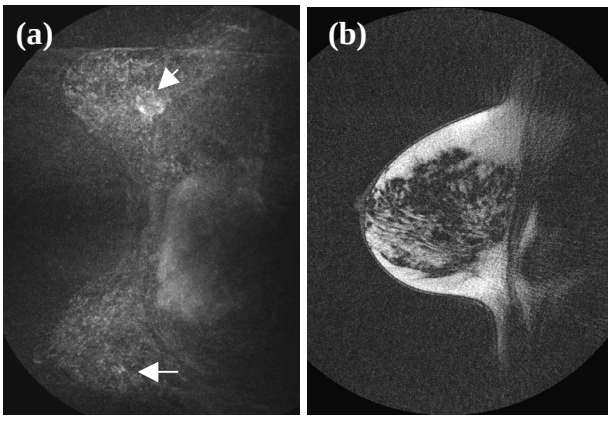

Figure 3: (a) PR-TRICKS 0.7 x 0.7 mm in-plane resolution. Malignant lesion in right breast (upper arrow) and benign in left breast (lower arrow). (b) Central slice from sagittal unilateral study.

CONCLUSIONS

We have shown the feasibility for breast MR using 3D PR-TRICKS for DCE-MRI of Breast. We are currently conducting a pilot study in 10 patient volunteers with known masses to assess the performance of this technique in a non-blinded study. Subsequent to this, the method will be applied to a larger patient study of 70 volunteers to assess in a blinded fashion the performance of the sequence for characterizing breast lesions in a clinical setting.

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