Breast Morphological and DCE MRI with SWIFT

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INTRODUCTION There are nearly 180,000 new cases of breast cancer each year (women) in the U.S. alone and over 40,000 deaths [1]. Mammography is currently the best radiological technique for breast cancer screening [2], but findings are frequently nonspecific. For this reason breast MRI, and especially dynamic contrast enhanced MRI have become standard of care for diagnosis of occult and ambiguous breast lesions, as well as for staging of treatment and surgery [3].

The SWIFT sequence (SWeep Imaging with Fourier Transform) has many desirable features for Breast MRI [4]. First of all, it is a rapid imaging sequence, with TRs of 2 ms or less having been achieved on our 4 T scanner. In addition SWIFT has extremely short dead time between excitation and acquisition making it sensitive to short T2 spins and associated novel contrast. Highly desirable is the immunity to R2* effects (due to short dead time) of injected Gd based contrast agents at high field, especially in the first pass and initial enhancement phase [5]. Here we report on initial progress in developing and optimizing a SWIFT protocol in a pilot study of breast patients.
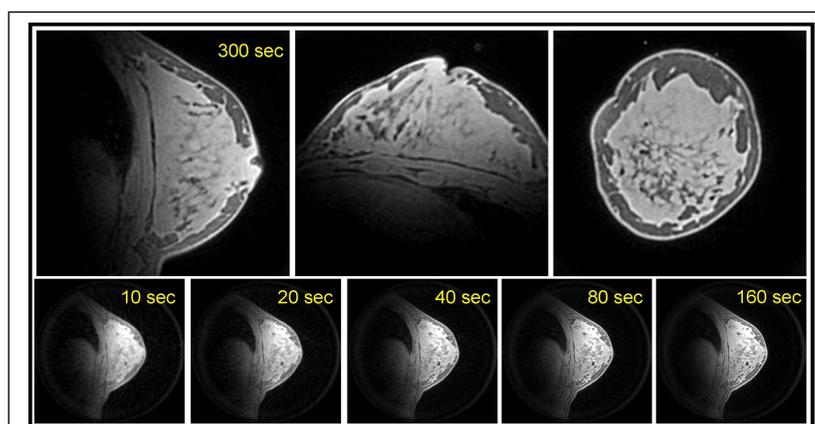

Fig 1. Top: Sagittal, Axial, Coronal reconstructions from 5 minutes of fat suppressed 3D SWIFT. Bottom: Increasing spatial resolutions achieved at decreasing dynamic temporal resolutions.
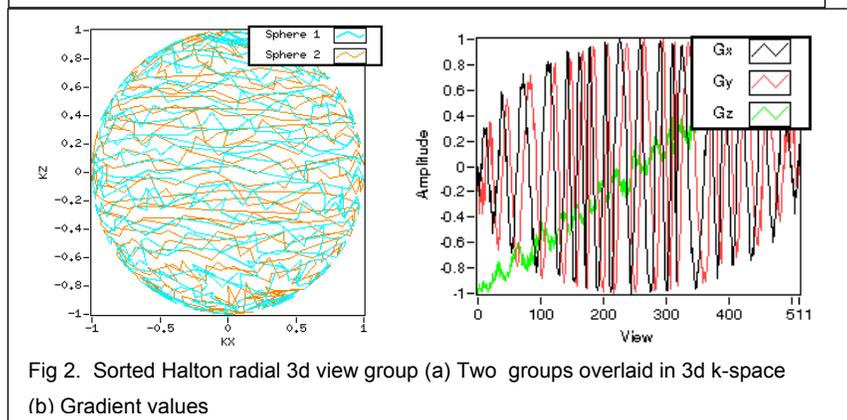

Fig 2. Sorted Halton radial 3d view group (a) Two groups overlaid in 3d k-space

(b) Gradient values

MATERIALS AND METHODS We have adapted and optimized the SWIFT sequence for combined morphological and DCE MRI of the breast. For this pilot study, scans are conducted on a 4 T human MRI system with an Oxford magnet, Siemens Sonata gradients, and Varian DirectDrive console. Initial imaging has been carried out on quad-transmit two-channel receive single breast coils modified to be SWIFT compatible (low short-T2 background). Each imaging session consists of preparation (frequency and power pre-scans, shim and standard GRE scout) plus 3 to 4 segments of 5-minute 62.5 KHz SWIFT acquisitions. TR=4.4 ms and flip angle ~8 degree (Ernst angle). A 5-minute SWIFT acquisition segment consists of a 512-view spherically distributed 3d radial group with 128 groups, totaling 65536 views. Interleaved CHESS fat suppression is inserted every 8-16 views with a 4 ms Gaussian pulse bracketed by a pair of 2 ms spoiling gradient ramps. Because the center of k-space is sampled with every radial view the sequence is self navigated for respiratory and other motion correction. The view ordering is a sorted pseudo-random Halton sequence [6,7]. Each 512-view group isotropically covers a full sphere of k-space and does not overlap with subsequent groups. See Figure 2a. Sorting minimizes the distance between view angles (and gradient jump) and limits the maximum acoustical noise to only 55 dB which is on the order of normal conversation. See Figure 2b.

RESULTS We show a representative 3d fat suppressed T1-weighted breast SWIFT reconstruction from a normal 29 year old volunteer. So far three volunteers have been imaged. The reconstruction is from one 5 min segment of SWIFT data are shown in Figure 1 Top. Reconstruction is achieved rapidly on a multi-core Linux PC using LabVIEW for SWIFT signal processing and gnu-fortran (gfort) for 2x oversampled gridding, density correction, and Fourier transformation [8]. Arbitrary slice series through the isotropic 3d dataset can be rapidly reconstructed without loss of image quality by interpolation re-slicing. Any number of view groups can be combined to trade off spatial vs. temporal resolution. Because of this the SWIFT data segments can be reconstructed into both high temporal resolution lower spatial resolution dynamic series and high spatial resolution lower temporal resolution morphological images, saving scanner time. See Figure 1 Bottom. We have begun to investigate motion correction of each individual group as well as view sharing for pseudo-temporal resolution and parallel acceleration. In addition, on our 4 T scanner, the SWIFT sequence is 45 dB quieter that the corresponding fat suppressed T1 weighted 3d flash sequence used previously for research Breast DCE imaging [9].

DISCUSSION AND CONCLUSION We have demonstrated a protocol for combined DCE and morphological breast MRI with an optimized SWIFT sequence. We are now accruing a cohort of 40 patients to establish initial feasibility for diagnosis of malignancy with biopsy as the gold standard.

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