Simultaneous Acquisition of Fat and Water Volume Images of the Breast with T2-like Contrast Using Vastly Undersampled Isotropic Projection (VIPR) SSFP

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INTRODUCTION

Diagnosis of findings detected by breast MRI requires correlation of T1, T2 and contrast enhanced signal intensities. Conventional and even fast T2 imaging techniques often require minutes per breast for adequate imaging and additional time loss is inherent as fat suppressed and unsuppressed images must be acquired and visualized separately. We present an application of the VIPR-SSFP (vastly undersampled isotropic projection acquisition SSFP) sequence to generate co-registered 3D isotropic fat and water volumes of the breast. The sequence's T2-like contrast can distinguish several relevant tissue types. Breast vasculature is also evident due to residual contrast from a DCE-MRI exam. Such a dataset may be useful in differential diagnosis of enhancing breast lesions and may localize pathology for study by other volume limited methods such as MR spectroscopy [2].

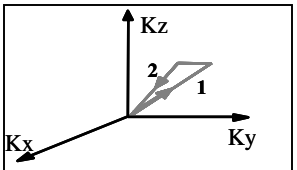

Figure 1. K-space trajectory for a single TR in the VIPR SSFP acquisition; sampling along ramps and dephasing and rephasing gradients allows for shortened TE and TR times.

MATERIALS AND METHODS

The VIPR-SSFP k-space trajectory, shown in Figure 1, collects two half-echoes in each repetition: one immediately after the rf excitation (1) and the other near the end of the TR (2) with a short tangential blip in between. Thus, two radial lines are sampled during each TR, inherently refocusing the transverse magnetization. Repeating this dual-half-echo trajectory throughout a sphere in k-space allows for reconstruction of a 3D image volume. Data acquisition during the frequency dephasing pulse, rephasing pulse and projection gradient ramps allows for a high acquisition efficiency and short TR.

Fat suppression is achieved by separating fat and water signal into separate image volumes using the LC-SSFP technique [3]. LC-SSFP requires sampling k-space twice, with the RF transmit phase alternating by π radians each TR in the first pass and remaining constant in the second pass. Linear combinations of these two passes generate the fat and water volumes. Optimal separation occurs when fat and water develop a π phase shift relative to each other during each TR, which is approximately 2.4 ms at 1.5 T. Thus, high resolution encoding is possible with the dual-half-echo implementation of VIPR-SSFP because extra encoding and rephrasing gradients do not lengthen the TR.

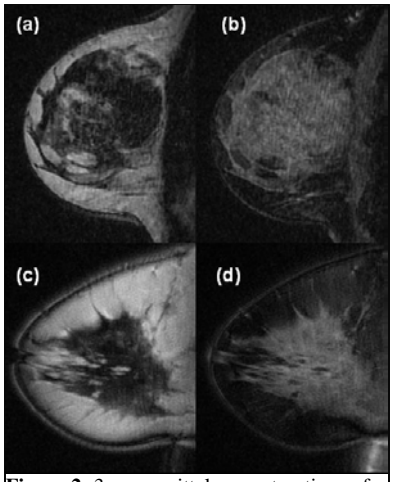

Figure 2: 3 mm sagittal reconstructions of fat and water images for two cases. Fat images (a and c), water images (b and d).

Six sets of patient data have been acquired to date. Unilateral breast images were acquired on a General Electric Signa 1.5T TwinSpeed scanner (GE Healthcare, Milwaukee, WI). Five were acquired with a 7-channel Biopsy Breast Coil (MRI Devices Corp., Waukesha, WI) and one was acquired using a 4-channel breast coil (MRI Devices Corp., Waukesha, WI). The VIPR-SSFP scan was acquired after a contrast enhanced scan, so it does not depict standard uptake and washout data, but adequate contrast remains in the breast to improve the SSFP signal. Contrast was administered as an intravenous injection (0.2mmol/kg) of Gd-DTPA (Omniscan, GE Healthcare). A 20 cm 3D volume covering the breast of interest was acquired with a 256x256x256 matrix resulting in isotropic resolution of .78 x .78 x .78 mm^3. Total imaging time for a single breast was 5 minutes with a TE/TR of 0.3/2.6. In the initial studies, a flip angle of 15° was used while more recent acquisitions have used a flip angle of 25° degrees to increase image contrast between different types of breast tissue.

All patients had a mass of ≥1cm detected on mammography or ultrasound. Pathology was confirmed by biopsy after the MRI exam. Two cases were malignant (1 infiltrating lobular carcinoma, 1 infiltrating ductal carcinoma), three were benign (3 fibroadenomas), and pathology is pending in the most recent case.

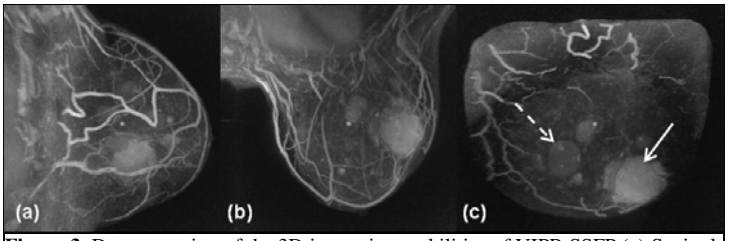

Figure 3. Demonstration of the 3D isotropic capabilities of VIPR SSFP (a) Sagittal MIP (b) Axial MIP (c) coronal MIP, thinned to demonstrate distinction of cyst and hematoma.

RESULTS AND DISCUSSION

Figure 2 shows reformatted 3mm sagittal slices of the fat and water volumes. Fat suppression was consistent across the image volume in all six cases. The fat signal was suppressed by an average of 78% based on comparison of signal data from manually selected ROIs throughout the images. Figure 3 demonstrates the 3D capabilities of the VIPR sequence; a MIP of fat suppressed data is shown in the sagittal, coronal, and axial orientations. The coronal MIP has been targeted to demonstrate the distinction of the cyst (dotted arrow) and the hematoma/associated tumor (solid arrow). The conspicuity of the vasculature, despite reduced contrast concentration due to the time lapse since injection, demonstrates the increased sensitivity of SSFP relative to T1-weighted imaging methods. The acquired sub-millimeter isotropic resolution, improves on the 3-4 mm slice thickness typical in conventional T2-weighted breast imaging. The total scan time of 5 minutes for both volumes is an improvement compared to conventional techniques in which a single breast fat-suppressed image volume requires 3-4 minutes and only provides one high resolution viewing orientation.

CONCLUSIONS

The short TR available with this sequence facilitates SSFP imaging in the difficult B0 homogeneity environment posed by the air/tissue interfaces of the breast. The image contrast available in the water volume due to consistent fat separation allows for the simultaneous distinction of fibroglandular tissue, cysts, vasculature, and pathology (Figure 3). Generating fat and water volumes from the same dataset simplifies co-registration and may allow the use of color display tools to visualize varying amounts of both species simultaneously [2]. This capability may provide necessary landmarks when comparing MRI and mammography. As almost every breast MRI study uses intravenous contrast, this exam could be flexibly appended onto any standard imaging protocol. Having demonstrated the feasibility of this method in a single breast acquisition, we next plan to develop bilateral functionality without substantially increasing scan time by applying parallel imaging methods well-suited to radial imaging [5].

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References 1. Liu AM, *et al*., *MRM,* 53:692-699, 2005. 2. Kuhl CK, et al., JMRI, 9:187-196, 1999. 3. Vasanawala SS, et al., MRM, 43:82-90, 2000 4. Werner N, et al., Proc. 11th ISMRM, p2529, 2003. 5. Griswold MA, et al., MRM. 44:602-609, 2000.