Rapid Acquisition of High Resolution 3D T_2-Weighted Water-Silicone Separated Breast Images

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Introduction: With the recent FDA announcement recommending regular MRI screening of silicone breast implants (1), there is a critical need for a robust and rapid MR imaging technique to visualize silicone ruptures. For confident diagnosis, silicone must be differentiated from normal breast tissues composed of water and fat. Techniques used for water-fat separation (2-4) can be modified to acquire silicone-only images by suppressing fat and separating water and silicone instead. This approach has been previously demonstrated with 2D fast-spin-echo (FSE) (5), and yields the T_2-weighted contrast that is desirable for imaging the long-T_1 and long-T_2 silicone spins. However, spatial resolution is limited in the slice direction due to the 2D nature of the acquisition, necessitating lengthy exam times with acquisition of 2D images in three separate image planes in order to assure adequate visualization of the implant. Previously, it has been impractical to acquire 3D T_2-weighted images due to prohibitively long scan times.

A new 3D FSE method eXtended Echo Train Acquisition (XETA) has been recently demonstrated (6) to significantly reduce 3D T_2-weighted imaging time through variable flip angle refocusing (6-8) and 2D accelerated partially parallel imaging (9,10) (referred to as "3D-FSE-Cube"). This technique was previously integrated with IDEAL (Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares estimation) to generate robust water-only and fat-only images in a clinically feasible scan time (11). The goal of this work is to utilize this sequence to provide comprehensive evaluation of silicone implant integrity with high near-isotropic resolution, silicone specific imaging in approximately 10 minutes. With near-isotropic resolution 3D data, image sections in any orientation can be generated to more accurately examine possible silicone ruptures.

Methods: 3D-FSE-Cube with IDEAL was modified to acquire three images with relative water-silicone phase shifts of $-\pi/6$, $\pi/2$, and $7\pi/6$ (-0.27ms, 0.81ms, and 1.88ms relative to the spin echo at 1.5T) (3). An adiabatic chemically-selective preparation pulse was used to suppress fat. This inverts fat and silicone, which after a short TI timed to suppress fat, leaves silicone with high (inverted) magnetization.

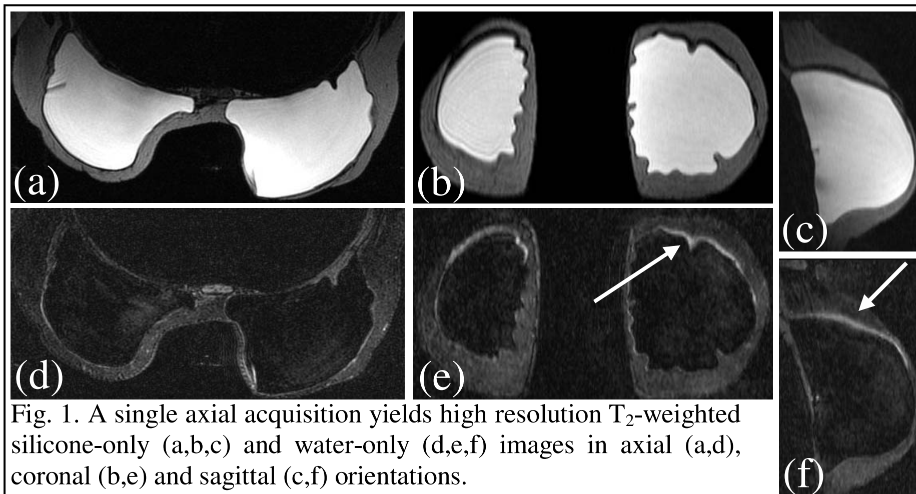

Fig. 1. A single axial acquisition yields high resolution T_2-weighted silicone-only (a,b,c) and water-only (d,e,f) images in axial (a,d), coronal (b,e) and sagittal (c,f) orientations.

After obtaining IRB approval and informed consent, volunteer data were acquired on a 1.5T TwinSpeed MR imaging system (GE Healthcare, Waukesha, WI) with an 8-channel breast coil (GE Healthcare Coils, Cleveland, OH). Imaging parameters included: TR = 3000 ms, TE = 110 ms, BW = $\pm$ 83.33 kHz, matrix = $320 \times 256 \times 102$, FOV = 320×320 mm^2 and 2 mm slice thickness. Parallel imaging acceleration was used with a factor of 2 along the right-left phase-encoding direction in an axial acquisition. ARC parallel imaging reconstruction with a full three-dimensional kernel (9) was used to generate the final images. The three water-silicone phase shifted images were processed using the standard 3-point IDEAL algorithm to reconstruct water-only, silicone-only, in-phase (water+silicone) and out-of-phase (water-silicone) images. The scan time was 11 minutes 30 seconds, achieving complete coverage, with near-isotropic spatial resolution of $1.0 \times 1.3 \times 2.0 mm^3$.

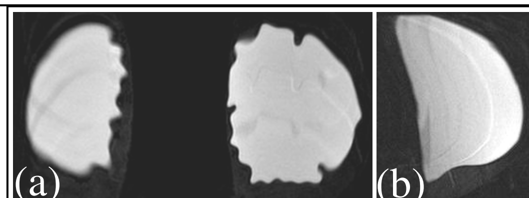

Fig. 2. 2D T_2-weighted silicone-only images with separate acquisitions in the coronal (a) and sagittal (b) orientations.

Results: Fig. 1 shows silicone and water separated images in different orientations. The images were acquired axially (fig.1a, 1d) and were reformatted into coronal (fig. 1b, 1e) and sagittal (fig.1c, 1f) orientations. Note the uniform separation, high SNR and high resolution in all of the silicone-only (figs. 1a-1c) images. The signal outside the silicone implants in figs. 1a-1c is the residual fat signal due to the TI being set slightly longer than the null time for fat. The high signal superior to the implants seen in 1d-1f (arrows) is believed to be fluid collection. For comparison, the corresponding silicone-only images acquired using 2D FSE-IDEAL with STIR are shown in fig. 2a (coronal) and fig. 2b (sagittal). The 2D images in all three orientations were acquired in 20 minutes of scan time, nearly double the scan time for the single 3D-FSE-Cube-IDEAL acquisition.

Discussion: We have demonstrated acquisition of near-isotropic, high resolution T_2-weighted 3D images of both water and silicone in a single scan. These images can be reformatted into any desired plane, allowing several 2D acquisitions to be replaced with a single 3D acquisition of reasonable duration. The use of parallel imaging along both phase encoding and slice encoding directions, which was not feasible with the coil used in these experiments, could further decrease the scan time and make complete isotropic resolution feasible. This new sequence allows the rapid assessment of silicone implants with isotropic resolution in approximately 10 minutes of total scan time.

References: 1) http://www.fda.gov/bbs/topics/NEWS/2006/NEW01512.html 2) Xiang Q et. al., JMRI 1997; 7: p.1002. 3) Ma J et. al., MRM 2002; 48: p. 1021. 4) Reeder SB et. al., MRM 2004; 51: p. 35. 5) Ma J. et. al., JMRI 2004; 19: p. 298. 6) Busse, et al. ISMRM 2007 p1702. 7) Busse RF et. al., MRM 2006; 55: p.1030. 8) Mugler III JP, ISMRM 2000; p.687. 9) Wang MRM 2006; 56:1389-1396 10) Beatty et. al. ISMRM 2007; p. 1749. 11) Madhuranthakam et.al., ISMRM 2007; p. 1631.