Quantitative Evaluation of Fat Suppression Techniques for Breast MRI at 3.0T

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Introduction

With higher intrinsic SNR and background suppression tissue due to longer T1, Breast MRI at 3.0T offers higher spatial resolution and greater contrast enhancement than 1.5T[1]. However, because greater B0 and B1 inhomogeneity, fat suppression, which is important for optimal lesion conspicuity, becomes more challenging[2]. While there are three choices of fat suppression (FS) commonly available, i.e. conventional or Quick FatSat (QFS), SPectrally selective Adiabatic Inversion Recovery (SPAIR)[3] and Water-only Excitation (WE)[4], none of them is very robust at 3.0T. The suppression of fat signal from breast tissue is often inconsistent and non-uniform. There has been no published evaluation of different breast fat suppression techniques to guide the optimization for clinical imaging. We, therefore, performed quantitative comparison of QFS, SPAIR and WE, as well as two-point DIXON (2PT DIXON), for fat suppression in breast MRI at 3.0T.

Methods

Breast MRI images of 10 patients (age 22 – 73) scanned on a 3.0T MRI system (Siemens TIM VERIO VB15) with a 7 channel breast coil (Invivo Corp) during the period of 8/5/2009 – 10/20/2009 were found to have images acquired from the same volume using the product version of 3D T1 weighted gradient echo pulse sequence (VIBE), but with different fat suppression techniques. Most of the imaging parameters were identical between different fat suppressed series: 160 transverse slices of 1mm thickness with 28 – 36 cm FOV, 448-512 matrix size and 80% phase resolution, except for 2PT DIXON where the matrix size is limited to 384. The suppression RF pulse was applied once for every 40 phase-slice encoding lines for QFS and every 128 lines for SPAIR. The TEs were 2.45ms and 3.75ms for 2PT DIXON.

From each data set, 5mm coronal slices were then created using multi-planar reformat (MPR) and only the middle slice between the nipple and the chest has been analyzed in this study. To evaluate the quality of fat suppression, the uniformity of signal intensity in the region without the glandular tissue was measured separately for each breast, assuming that the variation of signal intensity is due to incomplete suppressed fat or inadvertently suppressed water. Because the coil sensitivity profile also contributes to such variation, the non-fat suppressed images also acquired from the same volume were used for image intensity correction. After the glandular tissue region was manually traced and removed, circular regions-of-interest (ROIs) were manually placed to measure maximum and minimum signal intensity (I_{max} and I_{min}) in the remaining area under appropriate window/level settings. These steps are illustrated in Fig. 1. Fat suppression uniformity is quantified using the standard formula for measuring percent image uniformity, i.e. $[1- (I_{max}-I_{min})/(I_{max}+I_{min})]x100$. The perfect score for fat suppression uniformity is 100. The uniformity data were analyzed with an ANOVA test (SPSS 13.0) using the Bonferroni method of adjustment for multiple comparisons.

Results

Figure 2 shows the average fat suppression uniformities and their standard deviations for QFS, SPAIR, WE and 2PT DIXON. The technique used had a highly significant main ($p<0.001$) effect on the uniformity. Specifically, the 2PT DIXON method was significantly more uniform than all of the other methods ($p<0.044$), and none of the other methods were significantly different from each other ($p>0.240$). The scan time was longer for WE (75sec for WE versus 52 sec for QFS and SPAIR) due to the longer WE pulse scheme. The large standard deviations for QFS, SPAIR and WE indicate that there is a large variation of fat suppression uniformity between subjects and/or the left and right breast. Such result matches our clinical observation. The 2PT DIXON technique offers the most uniform fat suppression of breast MRI at 3.0T. The low standard deviation also shows that uniform fat suppression was achieved more consistently. There appears to be no correlation between fat suppression uniformity and coronal cross-section area (i.e. the size) of the breast for all four techniques.

Discussion

2PT DIXON technique relies on the phase difference between fat and water signal to generate fat and water only images, and therefore, is more immune to the B0 and B1 inhomogeneities at 3.0T. Since two echoes must be acquired with 2PT DIXON, the scan time is longer. Unlike WE, however, the expected increase in SNR from the combination of two echoes may be traded off to reduce scan time with various acceleration techniques.

References

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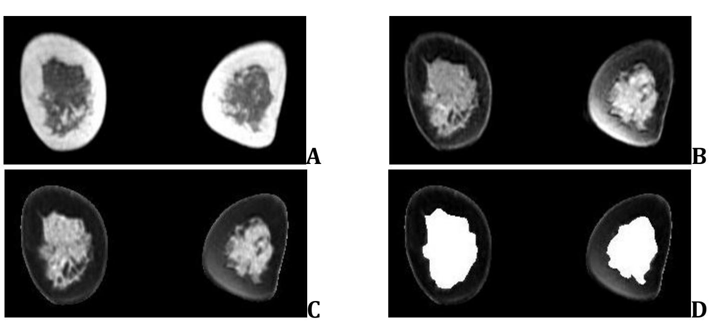

Figure 1: Post-processing steps to measure fat suppression uniformity. Non-fat suppressed coronal image (A) is used to correct signal intensity variation in fat suppressed image (B). The result is shown as (C). After the glandular portion is manually removed, the max. and min. signal intensities are measured in (D).

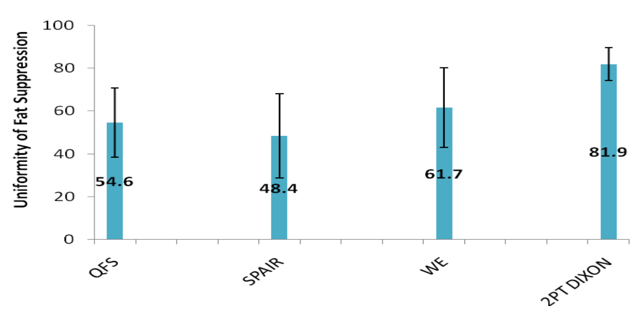

Figure 2: The average and stand deviation of fat suppression uniformity of four techniques. 2PT DIXON was significantly more uniform than any of the other three fat suppression techniques.