Prospective Motion Correction for T2- and Diffusion-Weighted Breast Imaging with FADE

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Introduction

T2- and diffusion-weighted imaging are useful as non-contrast-enhanced MRI techniques; however both are limited by low-resolution and blurring [1,2]. The Fast Acquisition Double Echo (FADE) sequence is a 3D steady-state sequence with two echoes per TR; spoiler gradients that separate the echoes provide diffusion weighting. FADE enables high-resolution T2- and diffusion-weighting imaging in clinically feasible scan times [3]. The spoiler gradients encode all sources of motion, including molecular, physiological, and bulk motion, all of which are present for breast imaging.

Although the FADE sequence provides high-quality images of other anatomies [4], the heart and lungs cause motion artifacts that degrade the quality of FADE images of the breast (Fig. 1). Here, we study four techniques for mitigating the effects of motion on FADE image quality for breast imaging.

Methods

To study the signal variations, projection (no y or z phase encoding gradients) and image data were acquired in volunteers at 3T using an 8-channel breast coil. Common scan parameters were $TE1/TE2_{eff}/TR$ = 10.4/49.6/30ms, 30° flip angle, 34cm FOV, 16 3-mm slices, 8000 µs G/cm FADE spoiler area in x-direction. We acquired low-resolution data (384×64) for the projections and high-resolution data (384×256) for the images. We tested four methods of reducing the motion artifact: breath holding, cardiac gating (T/W 20/50), respiratory gating (T/W 20/50), and elliptic-centric phase encode (PE) ordering.

The magnitude of the acquired echoes was plotted versus time and PE number for the projection scans to study the effects of the four methods and the quality of the corresponding images were compared. Results were validated in a patient exam.

Results and Discussion

With no motion compensation, the signal oscillations in time (Fig. 2) result in coherent image artifacts (Fig. 1). Elliptic-centric PE ordering results in incoherent artifacts because the data is not stored sequentially. We find that elliptic-centric PE ordering is the most consistent method for improving image quality because it isn't heavily dependent on parameter choices and doesn't affect the scan time or amount of data that can be acquired. Breath holding reduces the signal variation at the respiratory frequency, but the variation at the cardiac frequency remained. Although the image quality was very good for breath held images, the main drawback of the method is that the scan time is limited to a single breath hold, which limits the amount of data that can be acquired. Physiological (cardiac and respiratory) gating typically increases scan time by a factor of 2. Cardiac gating modifies the effective frequency of the signal variations relative to a non-gated scan due to the modified scan time. The ability of respiratory gating to remove the signal variation at the respiratory rate is dependent on correctly choosing the trigger and window values.

The signal variation causes image artifacts that can obscure the anatomy (Fig. 3a,b) and are extremely disruptive in the second echo where signal is lower due to the heavy T2- and diffusion-weighting. Elliptic-centric PE ordering (Fig. 3c,d) shows better delineation of the skin (Fig. 3c, arrow) and drastically improved depiction of the glandular tissue in Echo 2 (Fig. 3d). Images acquired with elliptic-centric PE ordering (Fig. 4) show very good image quality with clear depiction of a cyst.

Conclusion

The spoiler gradients that provide diffusion sensitivity in the FADE sequence are sensitive to all sources of motion, resulting in image artifacts. While breath holding provides the greatest reduction of signal variation, it limits the amount of data that can be acquired. Elliptic-centric PE ordering provides good artifact suppression without affecting the scan time. Parallel imaging can be used with centric ordering to reduce the scan time, which limits bulk motion during the scan. Future work will investigate retrospective corrections to further improve image quality.

By reducing the motion artifact, we are able to generate high-quality T2- and diffusion-weighted images in short scan times with low distortion. This improved image quality can be exploited to generate high-resolution ADC maps in the breast.

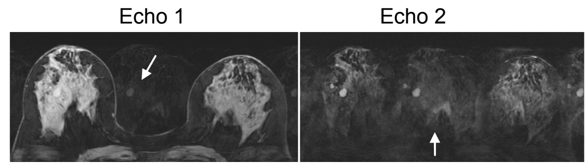

Figure 1 FADE images acquired without motion correction. The high-resolution images have useful contrast, but are corrupted by motion artifacts (arrows).

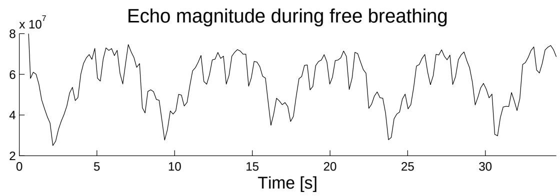

Figure 2 The magnitude of the echoes varies considerably between consecutive TRs. Oscillations are visible at the respiratory rate (large amplitude, ~9bpm) and the cardiac rate (small amplitude, ~50bpm). These oscillations cause the artifacts visible in Figure 1 (arrows).

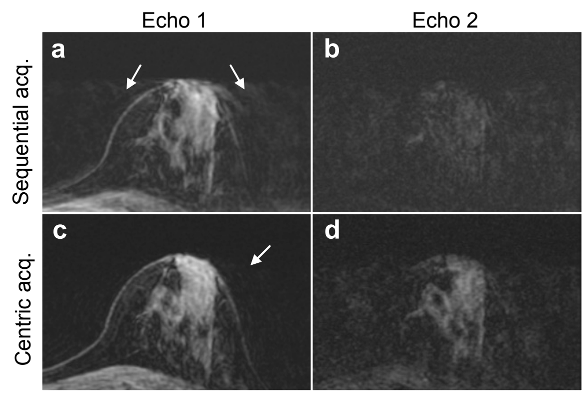

Figure 3 Volunteer images showing a reduction of the motion artifact (a, arrows) from a sequential PE ordering (a) to an elliptic-centric PE ordering (b). The reduction of the artifact makes the features of the glandular tissue more clearly visible, particularly in Echo 2

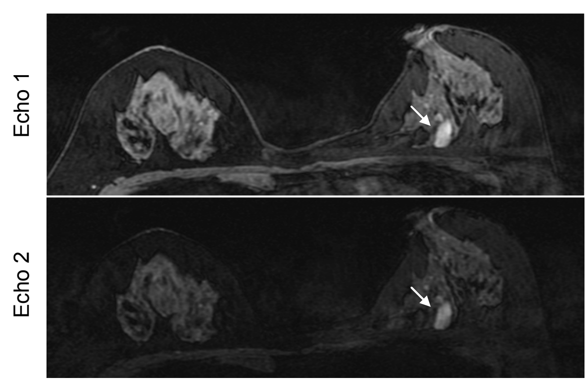

Figure 4 Patient images acquired with elliptic centric PE ordering. The images clearly depict a cyst (arrows) in a 48-year-old woman without significant motion artifact.

References [1] MRI 1990, 8:557-66, [2] Eur Rad, 2010, 20:1101-10, [3] ISMRM 2010, #366, [4] MRM 2009, 62:544-9