Initial clinical testing of RESOLVE: high-resolution diffusion weighted imaging at 3T

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Introduction: Diffusion weighted imaging (DWI), and in particular apparent diffusion coefficient mapping, has shown promise for improving the specificity of breast MRI.[2] Potential improvements in spatial resolution and diagnostic utility of DWI at 3 Tesla (T) are hampered by problems related to field inhomogeneity and image distortion. A readout segmented diffusion technique (RESOLVE)[1] permits the use of extremely short echo spacing independent of the spatial resolution, thereby reducing the image distortions. The purpose of this study was to compare lesion conspicuity on RESOLVE versus typical EPI diffusion imaging at 3T. A smaller subset of the lesions were used for ADC comparison between the two methods and to pathology.

Methods: A comprehensive retrospective search was done under IRB approval for studies with suspicious or biopsy-proven lesions, including foci, masses, and non-mass-like-enhancement, which had both RESOLVE and standard single-shot spin echo EPI (ss-EPI) diffusion imaging between July and October 2010. The RESOLVE technique used a readout segmentation factor of 5, with an echo spacing of 0.3 ms. The sequence acquires data from a 2D navigator to perform nonlinear phase correction and control reacquisition of uncorrectable data in real-time The imaging parameters were as follows: TR/TE = 7500-10000/60 ms (ss-EPI) and 8000-12000/64 ms (RESOLVE), averages = 3 (ss-EPI) and 1(RESOLVE), slices = 32-42 (minimum required to cover the entire breast), resolution = 1.8 x 1.8 x 4 mm^3, imaging time = 2:20-3:10 min for ss-EPI and 4:20 – 6:30 min. for RESOLVE. Two fellowship trained breast imaging radiologists rated the visibility of lesions as present or absent on RESOLVE and standard diffusion images. Radiologists also rated level of detail between the two diffusion sequences. For ADC value comparison, only biopsy-proven masses measuring at least 0.8-cm were used to ensure that lesions were adequately sampled with minimal volume averaging under both techniques. A MR physicist and board-certified radiologist with fellowship training in breast imaging jointly reviewed each case. For malignant lesions, benign lesions, and background, mean ADC values from freehand-drawn ROI's were averaged for each technique and compared. In addition, difference between mean ADC values as obtained by standard diffusion and RESOLVE was determined for each case and an overall average of these differences was determined.

Results: To date, 15 scans with both RESOLVE and standard diffusion have been performed on suspicious or biopsy-proven lesions (BIRADS 4, 5, and 6). Example is shown in Figure 1. Visibility of the 15 lesions as rated by the readers is shown in Table 1. All lesions detectable by standard diffusion were detectable by RESOLVE, however RESOLVE was able to demonstrate an additional 3 lesions per reader A, and 1 lesion per reader B. Although blinded, the readers universally chose RESOLVE images as more detailed in all cases. Of the 15 original scans, 5 contained biopsy-proven mass lesions measuring 0.8 cm or greater which could be used for ADC measurements. Four of these were biopsy-proven invasive breast cancers, and 1 represented a benign fibroadenoma. Average ROI was similar between standard diffusion and RESOLVE (0.29 +/- 0.07; 0.31 +/- 0.1). Results of ADC measurements are shown in Table 2, demonstrating good agreement between methods, with very low mean differences for each paired measurement, well within the standard deviation of each technique.

Lesion visibility by image method	RESOLVE (visible)	RESOLVE (not visible)
Standard DWI (visible)	9 / 7	0 / 0
Standard DWI (not visible)	1 / 3	5 / 5

Table 1: 2 x 2 contingency table for each reader shown as (reader A)/(reader B), comparing lesion visibility on RESOLVE versus standard diffusion. RESOLVE identified more lesions than standard diffusion for both readers.

Conclusions: Preliminary results suggest excellent lesion conspicuity under RESOLVE when compared to standard diffusion, as well as greater level of detail. ADC values are within those expected for malignant and benign lesions.[2] It is expected that additional data will further support RESOLVE as a robust, high-resolution diffusion weighted imaging technique at 3T. The improved detail and decreased image distortion available with this method has potential clinical utility as an adjunct to dynamic-contrast-enhanced breast MRI.

Lesion type	RESOLVE	Standard diffusion	Mean difference*
Malignant	0.82 ± 0.07	0.9 ± 0.1	-0.06
Benign	1.79 ± 0.09	1.80 ± 0.08	0.01
Background	1.9 ± 0.3	1.8 ± 0.4	0.04

Table 2: Apparent diffusion coefficient (x 10^{-3} mm^2/sec) for biopsy-proven masses measuring ≥ 0.8 cm, demonstrating good agreement between methods. *Mean difference between paired ADC values.

References: (1) Porter DA, et al MRM 2009; 62:468-75. (2) El Khouli, et al. Radiology; 2010; 256:64-73.
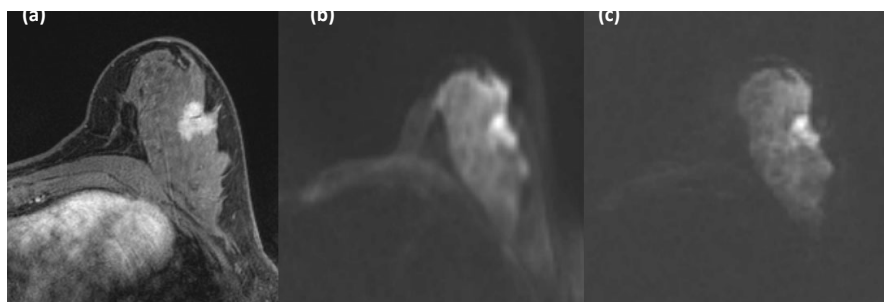
Figure 1: Example case of a 2 cm invasive cancer on (a) post-contrast T1, (b) standard diffusion, and (c) RESOLVE. RESOLVE images depict greater internal and edge detail of the lesion.