Assessment of Tumor Morphology on Diffusion-Weighted Breast MRI: Diagnostic Value of Reduced FOV High Resolution Diffusion-Weighted Imaging

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Target audience: Clinicians with an interest in breast diffusion-weighted imaging.

Purpose: Diffusion-weighted imaging (DWI) is a promising non-contrast technique to differentiate between benign and malignant breast lesions [1]. Single-shot diffusion-weighted (DW) echo planar imaging (EPI) is the most commonly used technique for DWI due to its insensitivity to motion and high signal-to noise ratio (SNR). However, DW-EPI suffers from blurring due to T2* decay and is particularly vulnerable to off-resonance due to the narrow effective bandwidth in the phase encode direction. To limit distortion, the typical resolution used for DW bilateral breast exams is about 2mm, while state-of-the-art contrast-enhanced techniques allow up to <1mm isotropic resolution. Multi-slice, high resolution DWI of targeted volumes using 2D RF pulses has been previously demonstrated [2]. The purpose of this study was to assess the diagnostic value of high-resolution reduced-FOV (r-FOV) DWI compared to conventional bilateral DWI (bil-DWI) and contrast-enhanced MRI (CE-MRI) to provide accurate characterization of breast lesions by revealing lesion margins and internal features that are important discriminators of malignancy.

Methods: Imaging was performed on a 3T whole body system (GE Discovery MR750, GE Healthcare, Waukesha, WI) using a 16-channel bilateral receive-only array coil (Sentinelle Medical, Inc, Toronto, ON, Canada).

Phantom study: Accuracy of r-FOV and bil-DWI was evaluated in a prototype breast phantom [3] developed at the National Institute of Standards and Technology (Gaithersburg, USA), consisting of several vials (10, 25 and 40% polyvinylpyrrolidone solutions) immersed in a mimicking fluid for fibro-glandular tissue and positioned 10-12cm off the magnet isocenter. The r-FOV and bil-DWI pulse sequences were identical (single-shot, spin echo EPI) except for the excitation RF pulse (r-FOV: 2D selective RF pulse; bil-DWI: slice-selective, spectral-spatial RF pulse) and the diffusion-encoding scheme (rFOV: Stajskal-Tanner; bil-DWI: twice-refocused [4]). Both r-FOV and bil-DWI were half Fourier acquisitions with the same effective echo train length, so that distortion and blurring were similar. Imaging parameters for r-FOV and bil-DWI are listed in Table 1.

	r-FOV DWI	Bil-DWI[a]	CE-MRI
FOV [cm²]	10x5	32^2-34^2	27^2-28^{2b}
Matrix size	128x64	160x160	512x320
True resolution [mm³]	0.8x0.8x4	≥2x2x5	0.5x0.8x1
TE/TR [ms]	61/3000	78/4000	2.2,3.3/6.3[c]
b values [s/mm²]	0,15,30,50,70,90,200, 500,750	0,600	-
NEX schedule	8,8,8,8,8,16,16,16	8,8	-
Acceleration factor	none	4	2.5x2

[a]Clinical protocol; [b]phase FOV = 1.2; [c]flip angle = 12°

Table 1: Imaging parameters

Patient study: 21 consecutive patients (51.3±9.1 years) with histologically proven breast cancer (15/21, 71.4%) or suspicious imaging findings (6/21, 28.6%) underwent r-FOV DWI, bil-DWI and CE-MRI. IRB approval and written informed consent were obtained.

Data acquisition: r-FOV and bil-DWI were performed before contrast injection (0.1 mmol/kg gadobutrol [Gadovist, Bayer Schering Pharma, Pittsburgh, PA, USA]) using the same protocol used for the phantom study (Table 1). The target for r-FOV DWI was determined by examining initial scout images and bil-DWI for focal abnormalities and marker clips. A 3D SPGR (SPoiled Gradient Recalled echo) acquisition with variable-density pseudo-random k-space sampling and Dixon-based fat suppression (DISCO [5]) was used for post-contrast T1-weighted imaging (Table 1).

ADC [mm²/s] in NIST breast phantom			
	Reference	r-FOV DWI	bil-DWI
10% PVP	1.8	1.69±0.1	1.63±0.03
25% PVP	1.0	0.99±0.1	0.94±0.02
40% PVP	0.65	0.61±0.09	0.54±0.02

Table 2: ADCs derived from r-FOV and bil-DWI show comparable values.

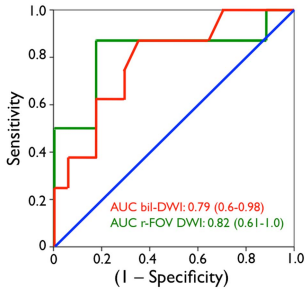

Figure 1: AUC values show improvement of r-FOV over bil-DWI.

Image analysis: Regions of interest (ROI) were drawn manually on both DW sequences separately to compensate for misregistration errors. ADC values were calculated using a monoexponential signal model. Three experienced breast radiologists independently reviewed all lesions. Image quality was scored according to five categories: sharpness (5 point scale: 1=unsharp, 5=very sharp), residual artifacts (4 point scale: 0=no artifacts, 3=severe artifacts, may interfere with diagnosis), distortion (4 point scale: 0=no distortions, 3=severe distortions, may interfere with diagnosis), perceived SNR (4 point scale: 1=poor, 4=excellent), and fat suppression (5 point scale: 1=failed, 5= excellent). Lesions were classified according to lesion shape and overall suspicion for cancer (BI-RADS 1-5) on the basis of r-FOV, bil-DWI and CE-MRI alone.

Results and discussion: Phantom experiments showed good agreement between ADC values derived from both r-FOV and bil-DWI and the reference values (Table 2). Twenty-two lesions (14 invasive ductal carcinomas (IDC), 5 benign lesions and 3 *in situ* carcinomas) were analyzed for the clinical study after exclusion of cysts and high-risk lesions. Both r-FOV and bil-DWI gave lower ADC values in invasive tumors than other lesions (r-FOV DWI: 1.01 x 10^{-3} mm²/s vs. 1.25 x 10^{-3} mm²/s, P=0.05; bil-DWI: 1.08 x 10^{-3} mm²/s vs. 1.44 x 10^{-3} mm²/s, P=0.003). r-FOV gave lower mean ADC values than bil-DWI (1.11 ± 0.32 vs. 1.24 ± 0.32 x 10^{-3} mm²/s, P=0.002), however they had similar discriminatory abilities based on ADC (Fig. 1). All readers found r-FOV images to be sharper than bil-DWI images (Figure 2-3). Perceived SNR was higher for r-FOV according to 2 readers (P≤0.005). Two readers found r-FOV images to be less distorted than bil-DWI (P=0.004, P=0.034). Lesion shape was found to be more predictive of malignancies for r-FOV (ROC AUC=0.74-0.91) than bil-DWI (ROC AUC=0.67-0.75), suggesting a more accurate assessment of tumor morphology with r-FOV DWI (Fig. 4). AUCs for predicting cancer based on BI-RADS classification ranged from 0.71 to 0.93 for r-FOV DWI, from 0.61 to 0.76 for bil-DWI and from 0.87 to 0.91 for CE-MRI.

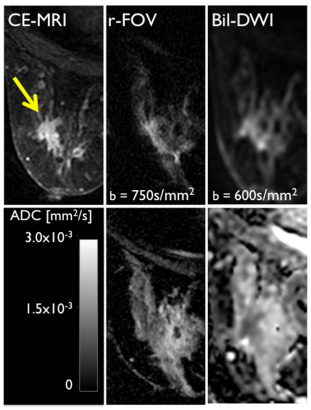

Figure 2: CE-MRI, r-FOV, bil-DWI and corresponding ADC values of a spiculated lesion.

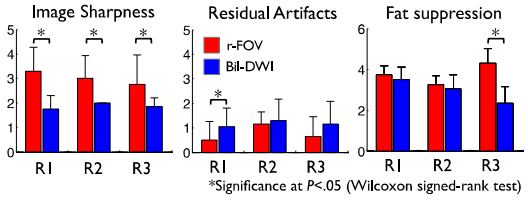

Figure 3: Qualitative evaluation of image quality.

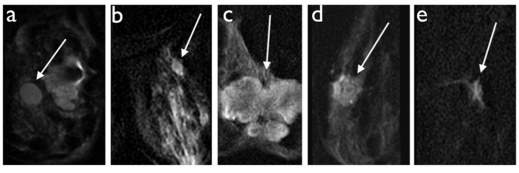

Figure 4: Example of round (a), oval (b), lobular (c), irregular (d) and spiculated (e) lesions on r-FOV DWI.

Conclusion: r-FOV DWI can help to discriminate between malignant and benign lesions by providing accurate depiction of tumor morphology.

References: [1] Sinha S. et al. JMRI 2002; 15: 693; [2] Saritas E.U. et al. MRM 2008; 60: 468; [3] Keenan K.E. et al. ISMRM 2014; [4] Reese T.G. et al. MRM 2003; 49: 177; [5] Saranathan M. et al. JMRI 2012; 35: 1484.