Improved Diagnostic Accuracy of Breast MRI through Combined Apparent Diffusion Coefficients and Dynamic Contrast-Enhanced Kinetics

S. C. Partridge[1], H. Rahbar[1], R. Murthy[2], X. Chai[3], B. Kurland[3], W. DeMartini[1], and C. Lehman[1]

[1]Radiology, University of Washington, Seattle, WA, United States, [2]Bioengineering, University of Washington, Seattle, WA, United States, [3]Clinical Statistics, Fred Hutchinson Cancer Research Center, Seattle, WA, United States

Introduction Breast MRI, particularly dynamic contrast-enhanced (DCE) MRI, has proven an important adjunct to mammography for screening high risk women and for determining extent of disease (1,2). However, despite high sensitivity for detecting breast cancer, DCE has a relatively moderate specificity. New techniques to improve the specificity and positive predictive value of breast MRI could reduce morbidity, economic costs, and psychosocial costs associated with unnecessary biopsies. Quantitative MRI approaches such as evaluating lesion kinetics on DCE and measuring the apparent diffusion coefficient (ADC) on diffusion-weighted imaging (DWI) can provide detailed tissue characterization to help discriminate benign and malignant lesions (3-5). Recent studies show that a combination of DWI and DCE characteristics can achieve high diagnostic accuracy (6) and that DWI can improve the diagnostic performance of conventional breast MRI (7,8). The aim of this study was to investigate the correlation between ADC and DCE kinetic characteristics of breast lesions, which has not been previously reported, and to evaluate the relative diagnostic value of each quantitative measure alone and in combination.

Methods After IRB approval, we retrospectively reviewed 100 consecutive breast lesions (27 malignant, 73 benign) that underwent breast MRI at 1.5T with both DCE and DWI (b=0, 600 s/mm^2) scans. We analyzed the DCE kinetics features of each lesion using a computer-aided assessment program (CADstream, Merge Healthcare Inc) and measured DWI features using in-house software (8). DWI and DCE features were compared by generalized estimating equations (GEE). Univariable and multivariable GEE models were used to identify features that optimally discriminated benign and malignant lesions based on: DCE kinetics (peak initial enhancement (PE); percent of lesion volume with persistent, plateau, and washout delayed phase enhancement; single worst curve type (washout>plateau>persistent)), and DWI apparent diffusion coefficient (ADC). The predictive abilities of the models were compared by receiver operating characteristic (ROC) analysis.

Results ADC was significantly lower for lesions exhibiting predominantly washout or plateau enhancement (mean ADC, $1.39 \pm 0.30 \times 10^{-3}$ mm^2/s), Fig 1, compared to those exhibiting predominantly persistent enhancement (mean ADC, $1.64 \pm 0.44 \times 10^{-3}$ mm^2/s, p=0.006). There were no significant correlations between ADC and PE or worst curve type. In univariate analyses, malignancies exhibited lower mean ADC (p < 0.001) and more often exhibited washout as the worst curve type (p=0.003) compared to benign lesions, Table 1. In multivariate analysis ADC and worst curve type were independent predictors of malignancy (p<0.001 and p=0.024, respectively). A model incorporating ADC and worst curve type produced higher area under the ROC curve (AUC = 0.85, 95% CI = 0.77, 0.93) than either ADC (AUC = 0.79, 95% CI = 0.70, 0.87, p=0.05) or worst curve alone (AUC = 0.69, 95% CI = 0.59, 0.78, p=0.007), Fig 2.
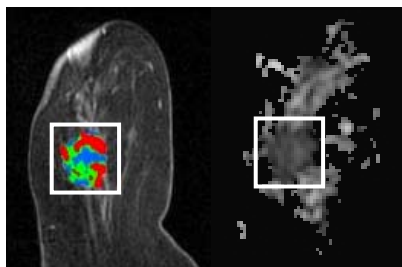

Figure 1. A 2.2cm invasive ductal carcinoma in an 85-year-old woman, which showed significant washout (red) on DCE and low ADC on DWI.
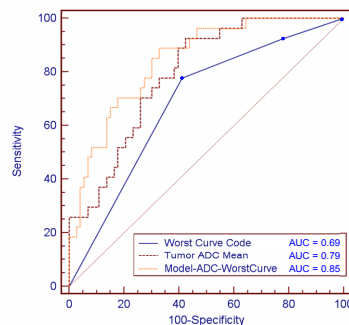

Figure 2. ROC curves

Table 1: Univariate comparisons of benign and malignant lesions, data given as mean±SD or n (%).

	Malignant (n=27)	Benign (n=73)	p-value
ADC ($\times 10^{-3}$ mm^2/s)	1.29 ± 0.26	1.72 ± 0.43	<0.001
PE (%)	140 ± 47	147 ± 51	0.59
Delayed Phase (%)			
%Persistent	62 ± 26	79 ± 24	0.005
%Plateau	25 ± 16	15 ± 16	0.01
%Washout	13 ± 17	6 ± 11	0.04
Worst Curve Type			
Persistent	2 (7%)	16 (22%)	0.003
Plateau	4 (15%)	27 (37%)	
Washout	21 (78%)	30 (41%)	

Discussion Our study is the first to correlate quantitative DWI and DCE kinetic characteristics, and demonstrates that lower ADC values (higher cellularity) are associated with more suspicious kinetics. Individually, ADC and worst kinetic curve type provided the greatest discriminative abilities. A model incorporating ADC and worst curve type provided significantly better accuracy in prediction of malignancy than either variable alone, suggesting that DWI provides distinct and complementary information to DCE for characterizing breast lesions. Future studies will determine the optimal way to incorporate ADC into the standard breast MRI assessment to reduce the number of unnecessary biopsies performed as a result of breast MRI.

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