Intravoxel Incoherent Motion in Breast Lesions at 3 Tesla

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Introduction

Diffusion-weighted (DW) signal of highly vascularized tissues shows microperfusion-related contribution due to the intravoxel incoherent motion (IVIM) effect [1]. The IVIM effect was found in locally advanced breast cancer, including invasive ductal carcinoma (IDC) and other breast malignancies [2], but not in normal fibroglandular tissue (FGT) [2,3]. We studied the IVIM effect in malignant and benign breast lesions and FGT imaged at 3 T.

Methods

Patients: The IRB approved this HIPAA compliant retrospective study with waiver of informed consent. The study included previously untreated patients 18 years of age and older, who underwent bilateral breast MRI at 3T in April and May 2011, including multi-b-value DW and post-contrast MRI, for evaluation of suspicious lesions, previously diagnosed breast cancer or family history of breast cancer. Patients with lesions were excluded if their lesions were smaller than 5 mm in diameter, lacked residual contrast enhancement or did not have biopsy results. Subjects with silicone implants and cases with motion and susceptibility artifacts were also excluded. Thirty eight patients (mean age, 52 years; range, 28–75 years) were included into the final analysis, 21 patients with lesions (13 malignant and 8 benign lesions) and 17 subjects with no lesions. One lesion per patient was considered. **MRI:** Imaging was performed at 3 T (Discovery MR750, GE Healthcare, Waukesha, WI) with a 16-channel breast coil (Sentinelle Vanguard, Sentinelle Medical, Toronto, Canada) and included fat-suppressed T2-weighted imaging, DW and post-contrast T1-weighted imaging. DW images were acquired with single shot spin echo EPI sequence (TR/TE = 4000/85.3 ms; 4 averages; FOV = 28x28 to 36x36 cm^2; slice thickness, 4–5 mm; acquired matrix, 128x128, interpolated to 256x256; 20 slices; b = 0, 30, 60, 90, 120, 400, 600, 800, 1000 s/mm^2). **Analysis:** Experienced radiologist placed ROIs on post-contrast images around lesions or FGT. ROIs were then transferred onto matching DW slices. Analysis of DW data was performed in Matlab (Mathworks, Natick, NJ). ADC was calculated by fitting signal at all b-values (ADC_{8b}) with monoexponential expression, $S(b) = S_0\exp(-ADC\cdot b)$, or using two b-values (ADC_{2b}, b = 60, 800 s/mm^2). Parameters of IVIM signal: $S(b) = S_0(f\cdot\exp(-D_p b) + (1–f)\cdot\exp(–Db))$, ($S_0 = S(b=0)$; perfusion fraction f, pseudodiffusion coefficient D_p and diffusion coefficient D) were determined from ROI-averaged signal in a segmented fashion [2]. D and f were first determined from monoexponential fitting of high b-value points (b≥400 s/mm^2) and then inserted into the biexponential signal expression to determine D_p. Goodness of fit was assessed using R^2. The mean parameter values among patients were compared using unpaired two-tailed Student's t-test. ADC and D for the same patient were compared using paired two-tailed t-test.

Results

Malignant lesions included IDC (n = 11), invasive lobular carcinoma (ILC, n = 1) and invasive mammary carcinoma (IMC, n = 1). Benign lesions included atypical lobular and ductal hyperplasia (n = 4), lobular carcinoma in situ (LCIS, n = 2), sclerosing adenosis (n = 1), fibrofatty tissue (n = 1). Patients with malignant lesions were younger than patients without lesions (mean age, 46 vs 57 years, p = 0.005) and patients with benign lesions tended to be younger than subjects without lesions (49 vs 57 years, p = 0.074). The IVIM contribution was present in 11/13 of malignant lesions (Fig. 1), but only in one benign lesion (Fig. 2) and in none of FGT ROIs (Table). Perfusion fraction was strongly affected by the scatter of high b-value data points. Distortion of DW signal at high b-values led to overestimation of perfusion fraction and therefore data were truncated at b = 800 s/mm^2. ADC_{2b} and ADC_{8b} were not significantly different. In all tissues, D was lower than ADC_{8b} ($p < 0.001$). ADC_{8b} was significantly lower in lesions than in FGT (malignant vs FGT, $p < 0.001$; benign vs FGT, p = 0.03) and tended to be lower in malignant than in benign lesions (p = 0.066). When D in malignant lesions was significantly lower than ADC_{8b} in benign lesions.

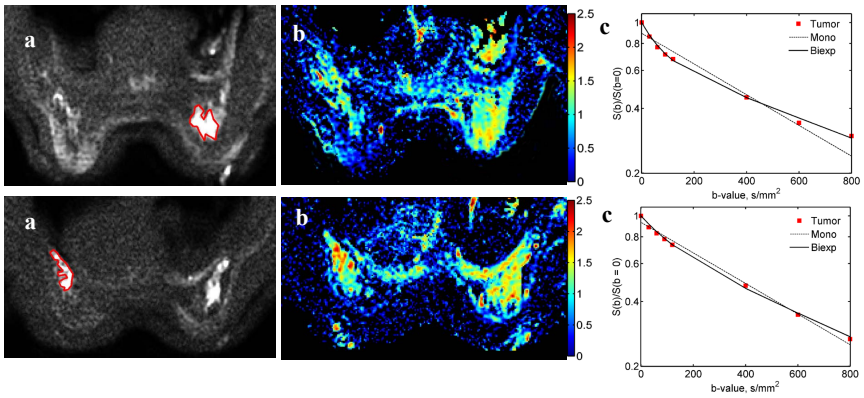

Figure 1: 51-year-old patient with ILC. a) Tumor ROI (red) is shown on b = 600 s/mm^2 image. b) ADC (10^{-3} mm^2/s) map shows low values in tumor and higher values in surrounding tissue. c) DW signal in the tumor ROI (red squares) with a monoexponential (dashed line) and biexponential fit (solid line). Monoexponential fit yields tumor $ADC_{8b} = 1.33\cdot10^{-3}$ mm^2/s; biexponential analysis produces a considerably lower D = $1.08\cdot10^{-3}$ mm^2/s, f = 0.31, $D_p = 13.6\cdot10^{-3}$ mm^2/s).

Figure 2: 54-year-old patient with LCIS. a) Tumor ROI on b = 600 s/mm^2 image. b) ADC map. c) DW signal in the tumor ROI and mono- and biexponential fits. Monoexponential $ADC_{8b} = 1.69\cdot10^{-3}$ mm^2/s; biexponential analysis yields D = $1.45\cdot10^{-3}$ mm^2/s, f = 0.15, $D_p = 16.9\cdot10^{-3}$ mm^2/s.

Table: Mean ADC and IVIM parameters in lesions and FGT

Parameter	FGT	Benign	Malignant
ADC_{2b} (10^{-3} mm^2/s)	1.94±0.29	1.60±0.43	1.29±0.32
ADC_{8b} (10^{-3} mm^2/s)	2.03±0.25	1.72±0.42	1.40±0.33
D (10^{-3} mm^2/s)	–	1.45*	1.16±0.34
f	–	0.15*	0.16±0.04
D_p (10^{-3} mm^2/s)	–	16.9*	8.52±2.53

*Only one benign lesion (LCIS) showed IVIM effect.

Discussion

IVIM was observed in all but two malignant lesions and was not detected in FGT, in agreement with previous reports [2,3]. The effect was also detected in one benign lesion. This observation is consistent with the tendency of malignant tumors to be more highly vascularized than normal breast tissues. Perfusion fraction in malignant lesions, predominantly IDC, was higher than the perfusion fraction reported in Ref. [2] and D_p was lower. Parameters of IVIM, D_p and f, are strongly affected by the data quality and method of analysis and are difficult to determine reliably. Quantitative measurements of IVIM per se are unlikely to be practical in breast lesions, yet the presence of the effect in the DW signal of a lesion may provide greater confidence in discrimination of malignant from benign lesions in addition to the discrimination based on conventional ADC values [4].

References

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