Evaluation of Stretched-Exponential Model for Diffusion-Weighted Imaging of breast lesions Using High b Values: comparison with monoexponential Diffusion Weighted Imaging

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Purpose: Breast cancer is the most commonly diagnosed type of cancers and alone accounts for 29% of all new cancer cases among women in 2012[1]. Diffusion-weighted imaging (DWI) has an increasingly important role in breast cancer detection and characterization. Conventional DWI signal decay in breast cancer is most commonly performed using the monoexponential model with two b values, which represents a linear decay[2]. However, the simple monoexponential fit cannot reflect the real signal decay features in breast cancer. As we know, breast cancer is a heterogenious disease and a stretched-exponential model (SEM) with high b values may better describe the diffusion-related signal decay and the tumor heterogeneity[3]. In this study, we obtained the parameters information using a stretched-exponential model with high b-values for normal breast and breast lesions and compared them to apparent diffusion coefficient (ADC) with conventional DWI in their ability to discriminate benign lesions and malignant tumors.

Methods: Informed consent was obtained from all patients. Seventy-seven patients with 52 malignant tumors, 20 benign lesions, 18 simple cysts and 23 contralateral normal breast tissues were imaged at 1.5 T MR scanner (Achieva, Philips Healthcare, Best, Netherlands). All patients underwent a standard bilateral breast MRI examination utilizing contrast enhancement and DW MRI with a 4-channel breast coil array in prone position. The DWI protocol was performed by using a single-shot spin-echo echo-planar imaging (EPI) sequence (TR/TE: 5065/66 msec, FOV: 300×300, resolution 200×196, section thickness 5mm, intersection gap 1mm, NSA: 3) with spectral presaturation inversion recovery and diffusion weighting factors of b 0, 700,1400 and 2100 sec/mm^2. Total scan time for the stretched-exponential scan was 362 secs. Stretched-exponential model parameters (ADCs and α) and ADC from mean monoepotential model were calculated with a manufacturer-supplied software (PRIDE DWI Tool, version 1.5, Philips Healthcare). Corresponding to the enhanced region on DCE MRI, a ROI was manually placed on each lesion as much as possible at the level of maximum transverse diameter of lesions (excluding necrosis or hemorrhage)on the SEM parameters images and the ROIs were kept the same on ADCs and ADC. ADCs, α and ADC values were obtained from normal breast tissues, cysts, benign lesions and malignant tumors. One-way ANOVA was used to compare the differences among the different parameters in different lesions. The Pearson correlation test was used to compare ADCs and ADC values. Comparison of Receiver operating characteristic (ROC) curve analyses was performed to evaluate the ability of the parameters for the detection of malignant lesions.

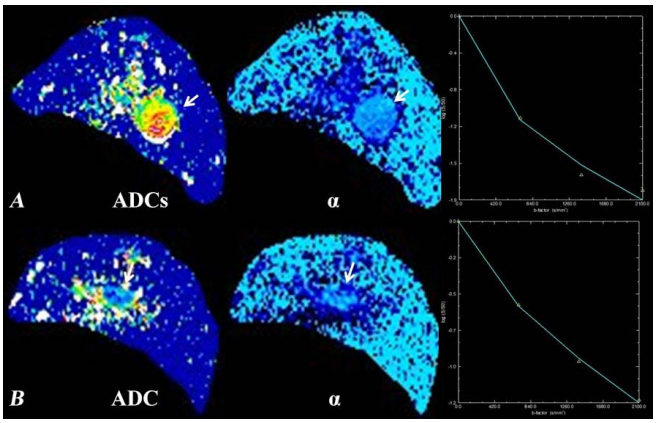

Fig.1. **A** a 26-year-old female with a fibroadenoma (arrow) ADCs and α maps shows the values were 1.52mm^2/s and 0.72. **B** a 45-year-old female with invasive ductal carcinoma (arrow) ADCs and α maps shows the values were 0.72mm^2/s and 0.71. The right curve demonstrated the signal decay curve with b values, respectively.

Results: There was good interobserver agreement on the measurements between 2 observers. ADCs, α and ADC values were significantly different among malignant tumors, benign lesions, simple cysts and normal breast tissues (P=0.000, respectively). ADCs and ADC values of malignant tumors were significantly smaller than those of benign lesions(Figure1), simple cysts and normal tissues (P = 0.000). The α was significantly different between benign or normal tissue and cysts, but not different between benign lesions and malignant tumors (Table1, Figure1). ADCs and ADC values demonstrated higher sensitivity and specificity in differentiating malignant tumors from benign lesions, with area under the curve (AUC) of 0.903, 0.870, respectively, while α with the lowest AUC of 0.550. There was no difference between ADCs and ADC value in differentiation (Figure2). There was a strongly positive correlation between ADCs and ADC values in the solid parts of lesions (Figure3). of tumors(R= 0.959; P<0.05).

	Malignant tumor	Benign lesions	Normal tissue	cyst	p
ADCs(mm^2/s)	0.98(0.87,1.08)	1.45(1.37,1.53)	2.38(2.29,2.48)	2.48(2.36,2.59)	0.000
α	0.64(0.62,0.66)	0.62(0.59,0.65)	0.52(0.48,0.55)	0.71(0.66,0.75)	0.000
ADC (mm^2/s)	0.87(0.79,0.94)	1.19(1.12,1.24)	1.93(1.78,2.08)	2.01(1.92,2.10)	0.000

Table 1. ADCs, α and ADC values of normal breast and breast lesions

Discussion & Conclusion: The stretched exponential model with high b values shows that it can reflect the intravoxel heterogeneity in the distribution of diffusion coefficients in different breast lesions. The ADCs can be used to differentiate benign and malignant lesions and has the highest specificity, comparing the conventional ADC, however, α is not different between benign and malignant tumors. Just as what researchers found in the study of prostate cancer[2], α cannot delineate well the cancer. It may be due to the used b values[4] and the parameter α may be further investigated.

Reference: [1] Siegel R, et al., Cancer statistics, 2012. [2] Jambor I, et al., MRM, 2014. [3] Bennett KM, et al., MRM, 2003. [4] Merisaari H, et al., MRM, 2014.

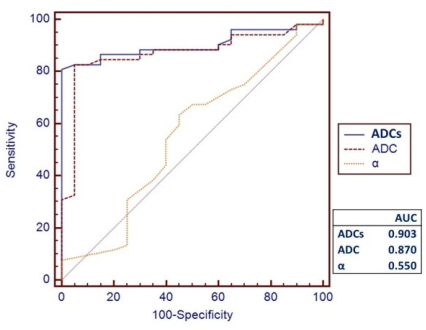

Fig.2. Comparisons of ROC curves of ADCs, αand ADC values for malignant tumors and benign lesions.

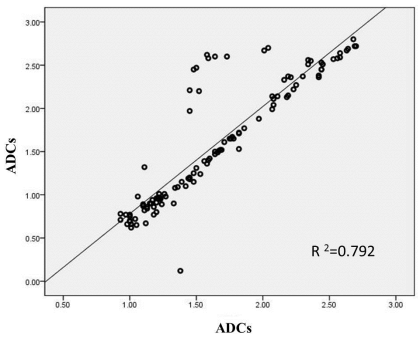

Fig.3. The correlation between ADCs and ADC values