A Preliminary Study of Diffusion Kurtosis Imaging for Assessment of Breast Lesions

Shiteng Suo[1], Fang Cheng[1], He Wang[2], Jia Hua[1], and Jianrong Xu[1]

[1]*Department of Radiology, Ren Ji Hospital, School of Medicine, Shanghai Jiao Tong University, Shanghai, China, China,* [2]*Philips Research Chinia, Shanghai, China, China*

Targeted audience:

Scientists and clinicians interested in breast diffusion-weighted MRI.

Introduction:

Conventional apparent diffusion coefficient (ADC) calculation suffers from a hypothesis based on uniform diffusion matrix that water diffusion follows a Gaussian behavior [1]. However, in biological tissues, water diffusion obeys a non-Gaussian distribution due to the presence of various barriers, such as cellular compartments and membranes [2,3]. As an extension of diffusion-weighted imaging (DWI), diffusion kurtosis imaging (DKI) is a promising imaging technique to depict the non-Gaussian water diffusion properties in vivo and can provide specific measure of tissue/cell complexities [2,4]. In this work, we investigated the potential role of DKI in assessment of breast lesions at 3.0 T.

Materials and Methods:

In this IRB-proved prospective study, 18 female patients (age range 23 to 72 years; mean 42.8 years) suspicious of breast cancer underwent bilateral breast MRI at our institution, and had their diagnosis confirmed by histopathology. Six patients were diagnosed with fibroadenoma, 11 with invasive ductal carcinoma (IDC) and 1 with mastitis. Imaging was performed on a 3.0-T scanner (Ingenia, Philips Medical Systems, Best, the Netherlands) using a dedicated 4-channel SENSE phased array coil. Anatomical axial T1- and T2-weighted images with and without fat suppression were first acquired. Axial DWI examination was performed by using a single shot SE-EPI sequence at 6 *b*-values (b = 0, 800, 1000, 1500, 2000, and 2500 s/mm^2) with three orthogonal gradient directions. Parameters for DWI included: TR/TE = 2681/82 ms, spatial resolution = 1.25 × 1.25 × 3 cm^3, 16 slices, NEX = 2, and parallel imaging technique using acceleration factor = 2. Dynamic contrast-enhanced MRI (DCE-MRI) was then conducted to confirm the localization of the lesions. Voxel-by-voxel curve-fitting method using the Levenberg-Marquardt algorithm was employed to fit the signal $S(b)$ as a function of the *b*-value to obtain the diffusion coefficient D and the kurtosis K using the following equation: $S(b) = S_0 \bullet \exp(-b \bullet D + b^2 \bullet D^2 \bullet K/6)$. In addition, the standard ADC was also calculated by using a conventional monoexponential fit with all *b*-values: $S(b) = S_0 \bullet \exp(-b \bullet \mathrm{ADC})$. Regions of interests (ROIs) were defined to encompass the whole lesion volume on ADC maps guided by DCE-MRI to avoid adjacent normal tissue or cystic components. Diffusion maps for each case, and the corresponding mean and standard deviation of each parameter within the ROIs were generated for statistical analysis.

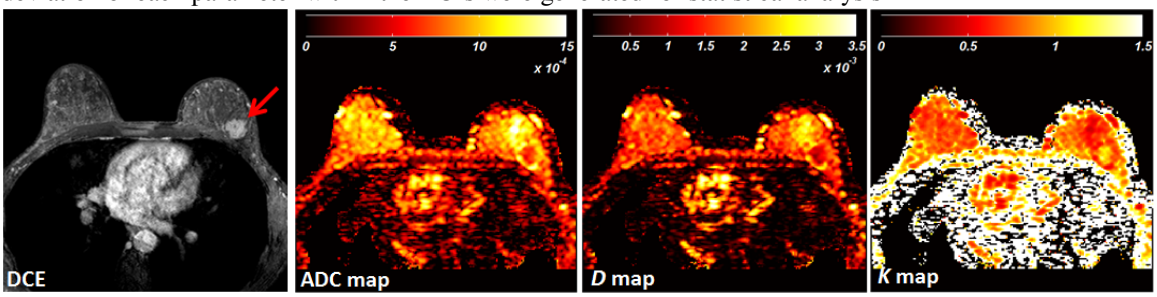

Fig. 1: One separate slice of diffusion images of a 32-year-old patient diagnosed with IDC, indicated by the red arrow. ADC: 0.695×10^{-3} mm^2/s; D: 0.940×10^{-3} mm^2/s; K: 1.002.

Results and Discussion:

A total number of 18 breast lesions larger than 1 cm in diameter were evaluated. The mean lesion volume (ROI size) was 10.656 cm^3 (range 1.263–28.441 cm^3) indicated on the ADC maps. The diffusion parameters for all cases are summarized in Table 1. In IDC, the ADC and D values were significantly lower than in fibroadenoma ($P < 0.001$, Mann-Whitney test). The K value was significantly higher in IDC compared to fibroadenoma ($P < 0.001$) and showed no overlap in our study. As for the one case with mastitis, the lesion tended to have a more restricted diffusion pattern as IDC and a large K value. These preliminary results demonstrate the feasibility of DKI in description of breast diffusion behavior, and an increased deviation from Gaussian diffusion in IDC compared to fibroadenoma, indicating more complex microstructure due to higher cell density or decreased permeability. The mastitis case with a large K value may also suggest tissue/cell heterogeneity, as the pathological findings showed inflammatory cell invasion and multinucleated giant cells within stroma.

Conclusion:

Although those preliminary results need to be validated with a larger sample size, they suggest that the DKI model can help describe the complex behavior of water diffusion in breast lesions, and the K value holds promise to give insight into the microstructure complexity and may help improve the diagnostic accuracy for breast lesions.

Table 1. The mean values and standard deviations derived for all diffusion parameters.

	IDC	Fibroadenoma	Mastitis
ADC (×10^{-3} mm^2/s)	0.665±0.078	1.167±0.141	0.593
D (×10^{-3} mm^2/s)	0.926±0.113	1.557±0.155	0.897
K	1.113±0.090	0.733±0.087	1.293

References:

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