Gaussian and non-Gaussian diffusion NMR imaging for endometrial carcinoma diagnosis

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We aimed to assess the usefulness of diffusion Kurtosis MRI (DKI) as a noninvasive, radiation-free method for detecting and evaluating endometrial cancer (EMC).
Endometrial cancer is the most common gynecological malignancy in developed countries, so it is necessary to develop more precise techniques for the prognosis of this kind of tumor. Diffusion Magnetic Resonance Imaging (D_MRI) uses the random movement of water molecules in tissue to obtain information about tissue microstructural rearrangment. In a homogenous environment, the movement of water would be completely random (Brownian motion) and described by a Gaussian motion propagator. Within biological tissues, the movement of water is hindered, restricted and obstruct by interaction with cell membranes. In these last case, the motion propagator is non-Gaussian.
Endometrial carcinoma and normal endometrium (Figura 1 and Figura 2, respectively) showed an increase in signal intensity on conventional D_MRI based on Gaussian diffusion model, named diffusion weighted image (DWI). However, it is usually difficult to distinguish between normal and cancerous tissue. Conversely, the diffusion coefficient D and the kurtosis parameter K obtained using DKI model, can provide a effective quantitative analysis of the microscopic diffusion of water in tissues and, therefore, of tissue structural changes at cellular level due to the cancer developing.
DKI is based on a non-Gaussian diffusion model that better reflects the diffusion within the complex microstructure of biological tissues. As a result, DKI improves tumor detection.
To test the potential of DKI MRI in the diagnosis of endometrial carcinoma (EMC), 13 patients who were suspected of having EMC and 9 healthy volunteers were enrolled. Mean (±standard deviation) patient age, who were suspected of having EMC at the time of MRI, was 70,46 (± 10,39) years.
Data were acquired using a 3T clinical scanner. The acquisition protocol included a Diffusion-weighted Spin-Echo Echo-Planar Imaging with repetition time/echo time, TR/TE=2000ms/77ms; pixel bandwidth=1953Hz , 12 px; matrix size=256x256, FOV 300x300, number of slices=from 9 to 31. The in-plane resolution was 1.2x1.2 mm^2 and the slice thickness 5mm. The diffusion encoding gradients were applied along 3 no-coplanar directions using ten different b-values (0, 30,50,150,500,800,1000,1500,2000,2500 s/mm2) and averaged over the three directions. The number of averaged signal (NS) for each b value was NS=2.
According to the DKI theory [1], signal intensity S decay was analyzed and DKI parameters were calculated for each voxel using the following equation:

$$S=S0\cdot\exp(-b\cdot D) + b^2\cdot D^2\cdot K/6 \quad (1)$$

where, S0 and S are the diffusion weighted signal at a b value of 0 s/mm2 and at b values other than 0 s/mm2, respectively; K indicates kurtosis and D indicates diffusivity . K represents the deviation from the Gaussian behaviour, and D represents diffusion coefficient corrected for non-Gaussian bias. We have also evaluated conventional diffusion (ADC) obtained using a Gaussian diffusion model. All images were processed using an in-house program developed with MatLab software (R2016b; MathWorks, Natick, MA). Moreover, a machine learning algorithm based on bugged tree was used in order to obtain D and K maps (Figure 3 and Figure 4, respectively) and improve the fit of data to function reported in Eq.1. Regions of interest (ROIs), which were approximately equivalent in size to the uterine wall layer thickness, tumor cross-sectional area, were selected on the uterine wall layers and tumors, respectively. Mean ± SD of K, D, and ADC values for the uterine wall layers and EMCs were calculated. Differences in K, D, and ADC values of the uterine wall layers and EMCs were statistically analysed using Anova test. In EMC, K (1.12 ± 0.30 u.a.), D (1.09 ± 0.30 *10-3 mm2/s) and ADC (0.85 ± 0.22 *10-3 mm2/s) were significantly different from those of all normal uterine wall layers. However, K discriminated between tumor and healthy tissue (K = 0.63±0.18 u.a.) with a lower p value (p = 0.0009) compared to the other parameters.
In conclusion, as DKI is based on a non-Gaussian diffusion model that better reflects the diffusion within the complex microstructure of biological tissues, K quantification improves EMC detection.

[1] J.H. Jensen, J.A. Helpern. MRI quantification of non-Gaussian water diffusion by kurtosis analysis NMR Biomed, 23 (2010), pp. 698-710.

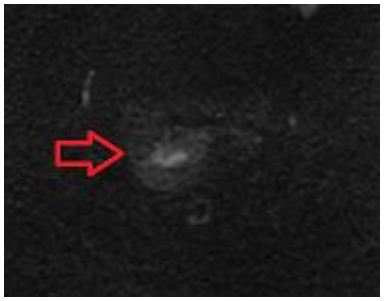

Figure 1. 71 year-old female with endometrial cancer indicated by an arrow . Axial diffusion-weighted image shows increased signal intensity in endometrium cancer at b value = 1000 s/mmm2.

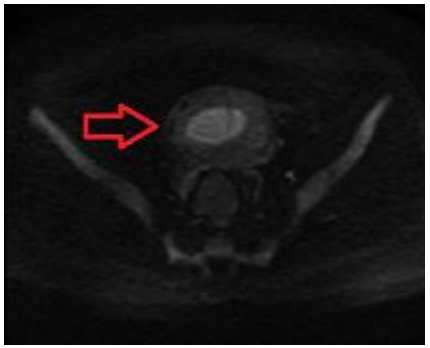

Figure 2. 46 year-old female with a healty endometrial indicated by an arrow . Axial diffusion-weighted image shows increased signal intensity in normal endometrium at b value = 1000 s/mmm2.

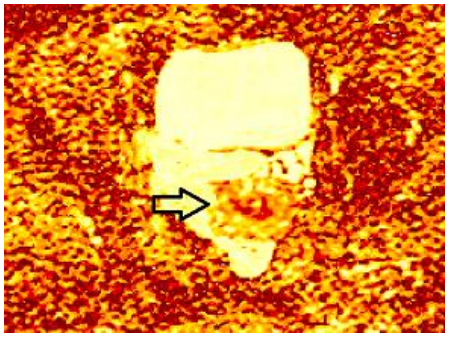

Figure 3. 71 year-old female with endometrial cancer indicated by an arrow. D map.

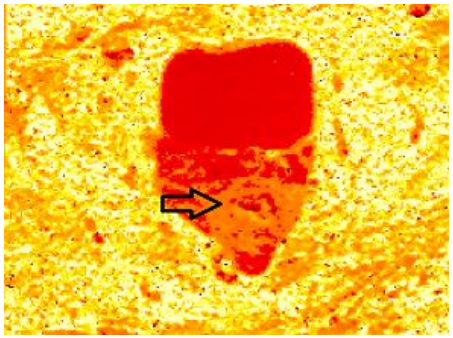

Figure 4. 71 year-old female with endometrial cancer indicated by an arrow. K map.