FUNCTIONAL MRI OF THE UTERUS WITH QUANTITATIVE T2, DIFFUSION-WEIGHTED, AND MAGNETIZATION-TRANSFER CONTRAST IMAGING

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Introduction: Current pelvic MRI protocols rely predominantly on anatomic sequences for evaluation of the uterus. Functional MR sequences may provide imaging biomarkers with added value for the detection, characterization, and follow-up of treatment response of benign and malignant uterine pathology. Examples of functional MR parameters that have been explored within the uterus in separate studies, although not collectively within the same cohort, include the T2 relaxation time[1], apparent diffusion coefficient (ADC) value[2], and magnetization transfer ratio (MTR)[3] of the uterus. Optimal application of these functional MR techniques in the diseased state requires an understanding of their behavior in the normal uterus. Therefore, the purpose of this study was to assess the T2 value, ADC value, and MTR in the three anatomic zones of the uterus as well as the correlation between these parameters.

Methods: 5 female volunteers (mean age 28.4±9 years) were imaged on a 1.5T Avanto scanner (Siemens) in this ongoing study, including T2-mapping, diffusion-weighted imaging (DWI), and magnetization transfer contrast (MTC) imaging, all performed in the sagittal plane with matching of slice positioning between these sequences. T2-mapping was performed using a multi-echo TSE sequence (TR 800, TE 15/29/53/63/82/102/121/140/16/179, FOV 180 x 180 mm, matrix 128 x 106, slice thickness 8 mm), with T2 maps reconstructed using an offline workstation (Leonardo, Siemens). DWI was performed using an SS EPI sequence (TR 2800, TE 81, b-values 0-500-1000, FOV 180 x 180 mm, matrix 128 x 106, slice thickness 8 mm), with in-line reconstruction of the ADC map. MTC imaging was performed using a spoiled gradient-echo sequence (TR 70, TE 4.76, flip angle 28°, FOV 180 x 180 mm, matrix 128 x 106, slice thickness 8 mm), with acquisition of the same slice both before and after application of a 15,000 microsecond Gaussian-shaped MT pre-pulse with a frequency offset of 2500 Hz and flip angle of 500° and using in-house modification of the MTC sequence to enable in-line reconstruction of the MTR map as $(S_0–S)/S_0$, where S_0 and S represent the signal intensity of each voxel with the MT pre-pulse off and on, respectively. Additional standard multiplanar T1-weighted and T2-weighted sequences of the uterus were obtained. A single radiologist obtained the T2 value, ADC value, and MTR within each of the endometrium, junctional zone, and myometrium in each patient as the average of three regions of interest (ROIs) manually placed within each of these regions. Care was taken to ensure that ROIs were placed on matching areas of each sequence via direct visual comparison and correlation with standard anatomic images. The mean T2 value, ADC value, and MTR were compared for the three anatomic zones of the uterus using the paired Wilcoxon test. Correlation between T2, ADC, and MTR was assessed using Spearman's correlation coefficient.

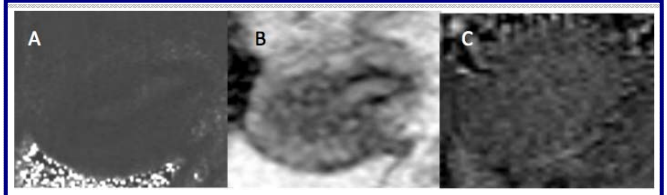

Figure 1. Sample T2 map (A), ADC map (B), and MTR map (C) from a single volunteer.

Results: Table 1 shows the mean ± SD for T2, ADC, and MTR in each of the three anatomic zones of the uterus. Although there were trends toward a greater T2 value in the endometrium than in other zones, a lower ADC value in the junctional zone than in other zones, and a lower MTR in the myometrium than in other zones, none of these differences reached statistical significance (p>0.06 for all comparisons) in these 5 patients. Table 2 shows the correlation between T2, ADC, and MTR for all three zones considered together. There was a moderate positive correlation between T2 and ADC (r=0.443), but poor correlation between T2 and MTR (r=0.079) as well as between ADC and MTR (r=-0.219).

Table 1: T2, ADC, and MTR for each of the myometrium, endometrium, and junctional zone in 5 volunteers (mean ± SD)

	Myometrium	Endometrium	Junctional Zone
T2 (ms)	77.7 ± 4.5	120.0 ± 47.3	73.8 ± 11.9
ADC ($x10^{-3}mm^2/s$)	1.26 ± 0.25	1.26 ± 0.16	0.69 ± -.13
MTR	0.07 ± 0.02	0.09 ± 0.02	0.09 ± 0.01

Table 2: Correlation between each of T2, ADC, and MTR for all three uterine zones combined (correlation coefficient and significance level)

		r	P
T2	**ADC**	0.443	0.0975
T2	**MTR**	0.079	0.7676
ADC	**MTR**	-0.219	0.4125

Conclusions: The higher T2 value within the endometrium is consistent with a larger free water content within this zone. The lower ADC within the junctional zone is consistent with decreased water diffusion resulting from the compact fibrous stroma within this zone. While MTR reflects differences in the content of large macromolecules between tissues, the reason for a somewhat lower MTR within the myometrium in this small sample is not clear. Small sample size likely contributed to the lack of statistical significance in this preliminary data. The positive correlation between T2 and ADC is consistent with restricted diffusion within tissues that have deceased water content and has been observed in other organs. The lack of correlation of MTR with either ADC or T2 suggests that this parameter reflects a characteristic of tissue not measured by either ADC or T2 and perhaps may provide information regarding uterine anatomy and pathology that is not provided by these other parameters. A knowledge of the correlation of functional MR markers with histologic features of tissue may impact therapy selection in a given patient; for instance, an ability to predict the composition of uterine fibroids may assist in optimal patient selection for uterine artery embolization[4-8]. Further data with more patients as well as with subjects with uterine pathology may give additional insight into the role of functional MRI, including DWI and MTC, for evaluation of the uterus.

References: [1] Varpula M et al. EJR 1993;16:90-94. [2] Messiou C, et al. Acta Radiologica 2009;50:696-701. [3] S Kobayashi et al. Radiology 1997;203:377-382. [4] Lenard ZM, et al. Radiology 2008;249:187-194. [5] Swe TT, et al. Radiation Medicine 1992;10:235-242. [6] Oguchi O, et al. J Ob Gyn 1995;21:107-117. [7] Yamashita Y, et al. Radiology 1993;189:721-725. [8] Funaki K, et al. J Minim Invasive Gynecol 2007;14:616-621.