The changes of uterine fibroids′ diffusion and perfusion status after MR-guided HIFU ablation evaluated from IVIM MR imaging with different b-values combination

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Introduction:

MR-guided HIFU which allows for 3D treatment planning and feedback of temperature deposition in the area to be treated is an emerging therapy technique which uses focused ultrasound to heat and coagulate tissue deep within the body, without damaging surrounding tissue. The IVIM MR imaging is a technique to estimate the tissue perfusion and diffusion by calculation of diffusivity parameters using multiple b-values DWI. Especially in well-perfused tissues, like uterine fibroids, the diffusion coefficient with b-values no larger than 200 s/mm^2 mainly provided information about the microcirculation of blood in the capillaries (perfusion)[1]. Therefore the purpose of this study is to retrospectively study the changes of uterine fibroids' diffusion and perfusion status 6 months after MR-guided HIFU ablation evaluated from IVIM MR imaging with different b-values combination.

Materials and Methods:

All 23 female patients (mean age, 44.3±4.3 years) with 23 uterine fibroids were given written informed consent. Multiple b-values DWI scan was performed on all patients before and 6 months after HIFU ablation using 3.0 T MR acquisition systems (Achieva TX; Philips Healthcare, the Netherlands) mounted with the clinical MR-guided HIFU system (Sonalleve MR-HIFU Fibroid Therapy System; Philips Healthcare, Finland). The IVIM MR imaging was acquired with 10 b-values as follows: 0, 25, 50, 75, 100, 150, 200, 500, 800, and 1000 s/mm^2. Data were analyzed by using DWI post-processing software performed in a proprietary programming environment (PRIDE; Philips Medical Systems).For all b-values no larger than 100 s/mm^2 and 200 s/mm^2, mono-exponential model was used to calculate the diffusion coefficient respectively. For all b-values, bi-exponential IVIM model was used to calculate the diffusion coefficient of pure molecular diffusion (D), the diffusion coefficient of microcirculation or perfusion (D*), and perfusion fraction (f). ROI containing the whole lesion was drawn by free hand on the maximum section of the fibroid using the software ImageJ (available at http://rsb.info.nih. gov/ij/) and IVIM parameters values were analyzed by using histograms. Histograms were plotted with the IVIM parameters on the x-axis with 256 bins, and the y-axis was expressed as a frequency in each bin. The following parameters were derived from the IVIM parameters histograms: (a) mean; (b) standard deviation; (c) the 25th, 50th, and 75th percentiles. To evaluate the changes of uterine fibroids' diffusion and perfusion status, all the IVIM parameters with different b-values combination before and 6 months after HIFU ablation were tested using paired t-test analyzed by using IBM SPSS Statistics 20.0 (Armonk, New York, USA). P <0.05 indicated a significant difference.

Results: All IVIM parameters (D, D*, f) values when all b-values were used at mean, 25th, 50th, 75th acquired before and 6 months after HIFU treatments were showed in Table 1. As shown in Figure 1, the D values increased a lot and f values decreased a lot 6 months after HIFU treatments. The D* values did not change obviously 6 months after HIFU treatments. The diffusion coefficient with b-values no larger than 100 s/mm^2 and 200 s/mm^2 respectively at mean, 25th, 50th, 75th before and after HIFU treatments are shown in Table 2. As shown in Figure 2, the diffusion coefficient with b-values no larger than 100 s/mm^2 decreased a lot 6 months after HIFU. The diffusion coefficient with b values no larger than 200 s/mm^2 also decreased 6 months after HIFU treatments but with no significant difference.

Discussion and Conclusion:

Our results indicated that IVIM MR imaging could show the changes of diffusion and perfusion status after HIFU treatments using all b-values and changes of perfusion status using low b-values. Furthermore, the measured diffusion coefficient in fibroid tissue was influenced by the choice of b-values combination. A significant decrease was found after HIFU treatments (p<0.05) when low b-values no larger than 100 s/mm^2 were used. The other low b-values combination showed no significant change in the diffusion coefficient 6 months after HIFU treatments. The reduced perfusion effect showed by the f value and the diffusion coefficient using low b-values was maybe due to occlusion and destruction of blood vessels during HIFU treatments. The observed change in the D value may indicate that the reduced perfusion is actually accompanied by an increase in extracellular fluid volume after ablation and increased permeability of capillary endothelial cells to macromolecular serum proteins. In conclusion, IVIM MR imaging could be useful for treatment evaluation after MR-HIFU ablation of uterine fibroids and may serve as a valuable tool in emphasizing such diffusion and perfusion changes by using all b-values and/or low b-values no larger than 100 s/mm^2.
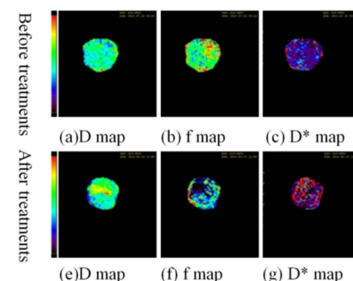

Figure 1 Fibroids IVIM parameters maps using all b-values before and after HIFU treatments
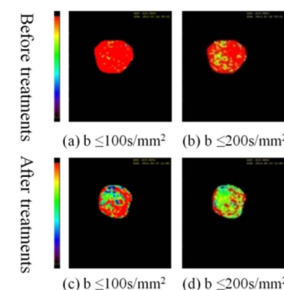

Figure 2 Fibroids diffusion coefficient maps using low b-values before and after HIFU treatments

Table 1 The changes of IVIM parameters using all b-values before and after HIFU treatments

	Before treatments	After treatment	p
Dmean (mm^2/s)	0.94±0.15	1.16±0.20	0.000
D25th (mm^2/s)	0.70±0.15	0.90±0.21	0.000
D50th (mm^2/s)	0.89±0.16	1.16±0.23	0.000
D75th (mm^2/s)	1.14±0.18	1.41±0.24	0.000
fmean	0.26±0.04	0.20±0.04	0.001
f25th	0.18±0.05	0.11±0.04	0.001
f50th	0.26±0.05	0.19±0.05	0.002
f75th	0.34±0.05	0.28±0.06	0.002
D*mean (mm^2/s)	50.5±10.1	54.9±10.3	0.187
D*25th (mm^2/s)	21.9±6.6	21.0±5.8	0.664
D*50th (mm^2/s)	40.0±10.1	40.9±10.2	0.775
D*75th (mm^2/s)	68.1±14.5	73.3±15.4	0.280

Table 2 The changes of diffusion coefficient before and after HIFU treatments using different low b-values combination

	b value(s/mm^2)	Before treatments	After treatment	p
Dmean (mm^2/s)	≤100	1.85±0.20	1.71±0.19	0.015
	≤200	1.81±0.24	1.70±0.22	0.145
D25th (mm^2/s)	≤100	1.40±0.32	1.25±0.27	0.078
	≤200	1.41±0.31	1.31±0.29	0.256
D50th (mm^2/s)	≤100	1.95±0.23	1.74±0.24	0.004
	≤200	1.86±0.29	1.72±0.26	0.134
D75th (mm^2/s)	≤100	2.38±0.16	2.22±0.18	0.007
	≤200	2.26±0.22	2.12±0.23	0.072

References [1] Ikink, M. E., et al. Diffusion-weighted magnetic resonance imaging using different b-value combinations for the evaluation of treatment results after volumetric MR-guided high-intensity focused ultrasound ablation of uterine fibroids. Eur Radiol. 2014. 24(9):2118-2127.