Clinical Evaluation of IVIM and DCE in Sarcoma

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Target audience: Physicists and radiologists interested in musculoskeletal MR imaging.

Purpose: Sarcoma is the most common musculoskeletal tumor for teenagers. In osteosarcoma, DWI correlates directly with tumor necrosis and is useful for monitoring of therapy response during chemotherapy [1]. Intravoxel incoherent motion (IVIM) separated perfusion and diffusion using multi-b-value DWI, which has been successfully applied to evaluation tumors in brain, kidney and liver. Dynamic contrast enhanced (DCE) imaging provides the pharmacodynamic information to characterize the diffusive transport of contrast across the capillary endothelium, which has been used to differentiate malignant and benign lesions in bone tumors [2]. The purpose of this study was to assess the clinical value of IVIM and DCE in sarcoma.

Methods: 7 patients with pathologically proven sarcoma were involved in this study. Patients were examined using a 1.5T MR scanner (MAGNETOM Espree, Siemens Healthcare, Erlangen, Germany) before surgery. T1-weighted spin echo sequences, T2-weighted fast spin echo sequence, and T1-weighted spin echo sequence with fat-saturation after contrast injection were all collected for the patients. IVIM was performed using a prototype single shot echo planar imaging (SS-EPI) sequence with 9 b values of 0, 20, 40, 60, 80, 100, 250, 500, and 750 s/mm^2 on 3 gradient directions. The FOV was 200×200 mm^2, matrix was 156×156, slice thickness was 5 mm with a gap of 1.5 mm, and TE/TR was 60/3100 ms. The perfusion fraction (PF), D-fast and D-slow were calculated by a full bi-exponential fitting of the equation $S(b)/S0 = (1-PF)\times\exp(-b\times D\text{-slow})+PF\times\exp(-b\times(D\text{-slow}+D\text{-fast}))$ pixel-by-pixel using the diffusion data series. DCE was performed using a 3D VIBE sequence with a voxel size of 1.2×1.2×4 mm^3, TE/TR of 2.4/5.6 ms and 40 measurement. T1-weighted images with flip angles (FA) of 2 and 15 degree acquired before contrast injection were used to calculate the T1 map, and then 10 degree FA was used for the dynamic measurement. For quantification, a region of interest (ROI) was chosen on the slice where tumors showed its largest enhancement. D-fast, D-slow, PF, Ktrans, Kep and Ve in tumors and healthy muscles were compared using Student's t-test.

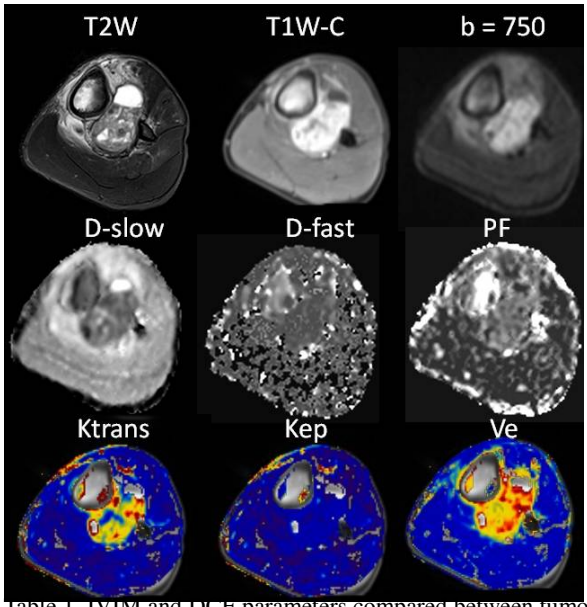

Figure 1: IVIM and DCE images from a 18-year-old patient with osteosarcoma in the right leg.

Results: Fig.1 shows example images of IVIM and DCE parameter maps in a patient with osteosarcoma. For IVIM, D-slow was lower in tumor masses than in healthy muscle, but D-fast and PF had no statistic difference between them. For DCE, Ktrans, Kep and Ve were higher in the tumor masses than in healthy muscles (Table 1).

Table 1: IVIM and DCE parameters compared between tumor masses and healthy muscles.

	ADC (10^{-3}mm^2/s)	D-slow (10^{-3}mm^2/s)	D-fast (10^{-3}mm^2/s)	PF (%)	Ktrans (min^{-1})	Kep (min^{-1})	Ve (%)
Tumor	1.03±0.08	1.03±0.07	0.32±0.02	0.09±0.01	1.12±0.19	2.71±0.78	0.51±0.07
Muscle	1.41±0.05	1.41±0.04	0.34±0.08	0.12±0.04	0.08±0.01	0.82±0.15	0.12±0.02
p-value	0.005	0.003	0.69	0.49	0.001	0.030	0.017

Discussion: Malignant tumors are characterized by increased microvascular permeability and angiogenesis, increased extracellular volume and higher cellularity. In IVIM imaging, the decreased D-slow in sarcoma reflected an aggressive growth of tumor cells. The unchanged D-fast and PF indicated the blood capillary density did not change in sarcoma. However, increased Ktrans value in DCE imaging reflected an increased microvescular permeability in sarcoma.

Conclusion: In sarcoma, ADC and D-slow were able to provide information about cell growth, and Ktrans provided information about tumor angiogenesis

Ref: [1] Uhl M. et al., Investigative Radiology (2006); [2] Jun-Yu G. et al., Journal of Magnetic Resonance Imaging (2009).