

Intravoxel Incoherent Motion Imaging of Renal Tumors: Subtype Differentiation Using Voxel-based Histogram Analysis

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Target Audience: Physicists and radiologists interested in DWI of renal tumors.

Introduction: Renal tumors are a heterogeneous group with variable biologic behavior and aggressiveness. It is not possible to discriminate between various subtypes with confidence on conventional imaging, and hence almost all patients undergo the same aggressive treatment – surgical resection. Recent studies have shown promise in discriminating various subtypes of renal cell carcinoma (RCC) based on DWI parameters¹⁻³. Specifically, intravoxel incoherent motion (IVIM) allows separation of cellular and vascular compartments without the need for exogenous contrast administration. A prior pilot study has shown that IVIM parameters may be useful in differentiating clear cell (ccRCC) from papillary (pRCC) and cystic (cyRCC) subtypes of RCC based on whole ROI analysis⁴. However, there is a need to improve discrimination of various subtypes as well as to distinguish benign lesions such as angiomyolipoma (AML) and oncocytoma (Onc) from malignant renal neoplasms. We postulate that tumor heterogeneity in cellularity and vascularity will be captured in IVIM metrics. Therefore, the goal of this study is to determine if IVIM voxel-based histogram analysis can differentiate various subtypes of renal tumors.

Methods: 41 patients with renal tumors who underwent surgery and had histopathology available are included in this HIPAA-compliant, IRB-approved, single institution prospective study. In addition to a routine renal MR exam performed on a 1.5 T system (MAGNETOM Avanto, Siemens, Erlangen, Germany), all patients were imaged prior to surgery with axial respiratory-triggered, twice-refocused, bipolar gradient, single-shot echo planar DWI with tridirectional, trace-weighting diffusion gradients (TR/TE, 2700-4000/76 ms; matrix, 192 x 144-192; voxel size, 1.8 x 1.8 x 6 mm; 15-32 axial 6 mm slices; *b* values 0, 50, 100, 150, 250, 400, 600, and 800 s/mm²; 2 averages) before the administration of gadolinium-based contrast. DWI DICOM data was imported into a custom-developed software package (Igor Pro 6, Wavemetrics) for analysis. Manual regions of interest were drawn around the entire lesion on each slice. A monoexponential decay curve was used to generate an ADC map across all *b*-values, whereas a 2 compartment biexponential model was fitted to the diffusion signal data using a segmented algorithm to extract the IVIM parameters perfusion fraction (*f_p*), tissue diffusivity (*D_t*), and pseudodiffusivity (*D_p*) for each voxel⁵. Histogram analysis provided the maximum, minimum, and mean of each IVIM parameter and histogram metrics of heterogeneity (standard deviation, skewness, and kurtosis) similar to prior work in contrast-enhanced imaging⁶. IVIM data were correlated with histologic subtype of tumor using two-tailed t-tests.

Results: Figure 1 demonstrates differences in IVIM parameters *f_p* and *D_t* as well as in histogram features between ccRCC (1a-d) and Onc (1e-h), a benign lesion. Figure 2a summarizes the average *f_p* and *D_t* amongst 6 renal tumor subtypes, whereas figure 2b shows benign lesions (Onc and AML) can potentially be differentiated from malignant lesions (ccRCC and chRCC) by incorporating the histogram heterogeneity parameters histogram kurtosis (*K_{hist}[f_p]*) and standard deviation of *D_t* (*σ[D_t]*). Among the 6 different subtypes of renal tumors included in our study, we found significant differentiation in 123 out of 480 (25.6%) possible comparisons, a percentage above that expected from a null hypothesis (5%). Of these, weighted averages of 12.75 originated from the heterogeneity parameters (sd, skewness, kurtosis), 15.5 from extrema (max or min), and 20.5 from average values.

Discussion: Our preliminary study demonstrates that IVIM parameters with inclusion of histogram measures of heterogeneity can help differentiate malignant from benign renal lesions as well as different subtypes of renal cancers, which in turn could potentially have a clinical impact with regard to treatment planning for patients with renal tumors. Future studies with a larger number of subjects are required to validate our results. The impact of using alternative fitting or textural algorithms in addition to the biexponential model also warrants investigation⁷⁻⁹.

References: [1] Rheinheimer S, et al. Eur Jour Radiol 2012; 81:310-16. [2] Doganay S, et al. Clin Radiol 2011;66(5):420-25. [3] Erbay G, et al. Acta Radiol 2012;53:359-65. [4] Chandarana H, et al. Invest Radiol 2012;47:688-696. [5] Chandarana H, et al. Invest Radiol 2011;46:285-291. [6] Chandarana H, et al. Radiology 2012;265(3):790-8. [7] Orton MR, et al. Magnetic Resonance Medicine 2013. [8] Freiman M, et al. Med Image Anal 2013. [9] Ahmed A. et al. JMIR 2013.

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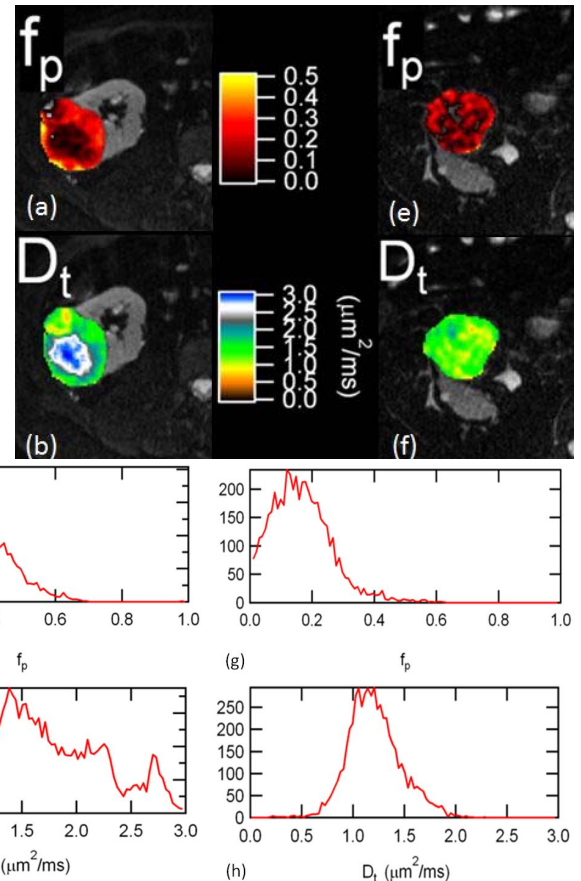


Figure 1: IVIM and histogram analysis of clear cell RCC (a-d) vs. oncocytoma (e-h).

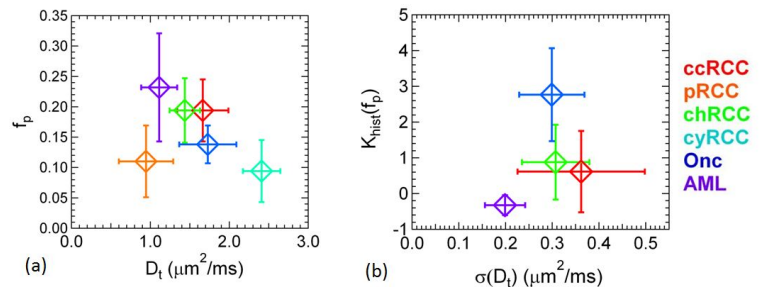


Figure 2: *f_p* vs. *D_t* (a) and *K_{hist}[f_p]* vs. *σ[D_t]* (b) scatter plots of 6 renal tumor subtypes. Error bars reflect standard deviations within subject groups.