Diffusion weighted imaging with biexponential analysis of intravoxel incoherent motion in assessment of renal lesions: Preliminary experience

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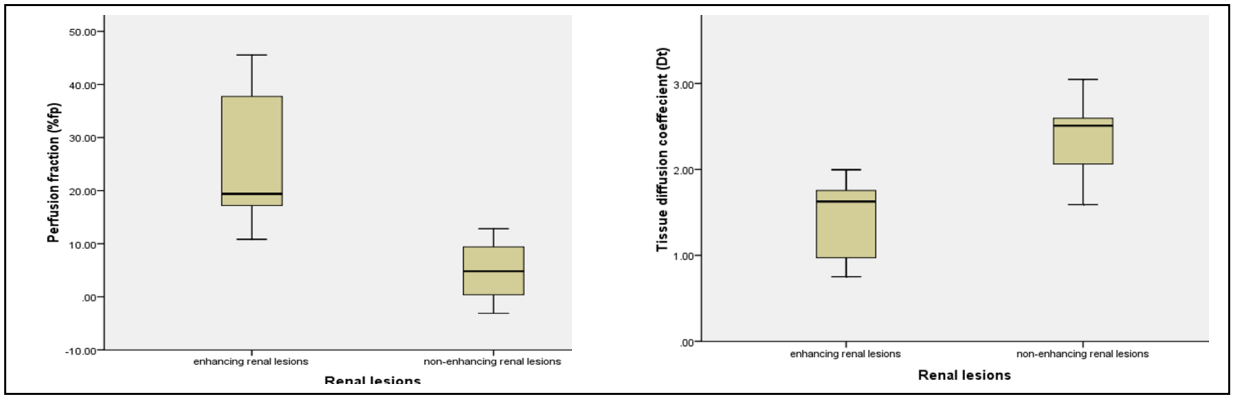
Purpose: Diffusion weighted MRI (DWI) is influenced by perfusion effects at lower b-values, an effect sometimes termed intravoxel incoherent motion (IVIM). Movement of blood in microvasculature can be modeled as pseudo-diffusion and this perfusion effect can be separately determined if both low (<200 sec/mm^2) and high b values are used. The purpose of our study was to calculate perfusion fraction (f_p) and tissue diffusivity (D_t) parameters obtained with multi-b DWI and determine if these parameters can distinguish enhancing from non-enhancing renal lesions using gadolinium-enhanced MRI as the reference standard. Our goals include (1) identifying alternative biomarkers of malignancy to standard methods requiring gadolinium chelates and (2) differentiating between two distinct processes (tissue perfusion and diffusion) that contribute to ADC to determine whether one or both may be used as a more specific marker for malignancy or treatment response.

Materials and Methods: In this HIPAA-compliant IRB-approved prospective study; 25 consecutive patients with suspicion of renal mass were imaged at 1.5 T utilizing T1 3D fat-suppressed pre and post contrast GRE (VIBE) as part of our routine renal MRI protocol. Transverse breath-hold single shot echo planar (EP) DWI was performed prior to contrast administration covering the region of the renal mass using the following parameters: TR/TE 910-1000/76-78 ms, FOV 375 x 350, matrix 192 x 192, parallel imaging factor of 2, slice thickness 6 mm, 7 axial slices with inter-slice gap of 1mm, 8 b values (0,50,100,150,250,400,600, and 800 sec/mm^2), and one average. Acquisition times averaged 20 seconds (range 16 – 22 sec). 5 patients were excluded (no mass seen in 3 cases, low signal to noise ratio (SNR) on high b value acquisition in 2 cases). Hence, 20 patients constituted our study cohort. A large region of interest (ROI) was manually placed on the index lesion on the b0 image by an observer blinded to patient's clinical information and contrast enhancement and copied to other b value images to derive signal intensity (S(b)) values. A biexponential model was employed to describe the behavior of S(b) in the renal masses. To perform the biexponential fit, first a monoexponential fit to the asymptotic, high b-value portion of the acquired data was performed. The decay rate of this fit determines the tissue diffusivity D_t. Then, in the second step the low-b intercept S_{int} was used to determine the perfusion fraction, according to $f_p = (S(b=0) – S_{int}) / S(b=0))$. As a reference method for tumor perfusion, the % enhancement on post contrast images was calculated: (SI_{max}post contrast – SI pre contrast)/ SI pre contrast x 100%, and lesions that exhibited > 15% enhancement were considered to be enhancing lesions. Single compartment apparent diffusion coefficients (ADC) were estimated from monoexponential fitting to all b-values (ADCtot) or a select few (b=0,400,800).

Results: 21 lesions were identified; 10 enhancing and 11 non-enhancing on gadolinium enhanced MRI. f_p was significantly higher 0.248 vs. 0.081) and D_t was significantly lower (1.46 vs. 2.18 x10^{-3} mm^2/s) in enhancing masses compared to non-enhancing lesions. There was moderate significant correlation between contrast enhancement and f_p (r =0.64, p=0.0041). f_p and D_t demonstrated higher sensitivity and specificity in differentiating enhancing from non-enhancing lesions compared to ADC_{total} and $ADC_{0\text{-}400\text{-}800}$, as reported in a recent study.

Parameter	AUC	P value	Threshold	Sensitivity	Specificity
f_p (%)	0.909	<0.0001	> 12.8%	90.0%	90.9%
D_t	0.845	0.0001	≤ 1.75	80.0%	81.8%
$ADC_{0\text{-}400\text{-}800}$	0.809	0.0014	≤ 2.0	70.0%	81.8%



Discussion: In the preliminary study, perfusion fraction (f_p) obtained with IVIM DWI shows significant correlation with contrast enhancement and can be used along with D_t to discriminate enhancing from non-enhancing renal lesions without the use of exogenous contrast agent. Biexponential fitting reduces the sampling-dependent systematic error associated with single compartment apparent diffusion coefficient (ADC) model that relies on monoexponential fitting. The potential additional benefits of simultaneous biomarkers of cellularity (restricted tissue diffusion D_t) and vascularity (elevated perfusion fraction f_p) remain to be explored with histopathological correlation studies.

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