Combined Diffusion-weighted-, Blood oxygen level dependent- and Dynamic contrast enhanced-MRI for assessment of renal cell carcinoma.

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Purpose: Dynamic Contrast-Enhanced (DCE)-MRI, Diffusion weighted Imaging (DWI) and Blood oxygen level dependent (BOLD) MRI for evaluation of primary Renal Cell Carcinoma (RCC) (1,2,3), however no study has assessed the correlation of the derived parameters and the potential complimentary information provided by these techniques. In tumors other than RCC, Blood oxygen level dependent (BOLD) MRI has shown moderate correlation with DCE-MRI (4). The purpose of this study was to investigate the feasibility and correlation of DWI, BOLD and DCE-MRI for assessment of cellularity, oxygenation, perfusion and permeability of primary RCC. We evaluated if the different techniques yield competing or complimentary data.

Material and Methods: Fourteen patients with clear cell and 4 patients with papillary RCC were examined with DWI, BOLD MRI and DCE-MRI at 1.5T. Diffusion weighted images were acquired in breath-hold technique with a coronal echo-planar-imaging sequence (TR 3000ms; TE 98ms; slice thickness 8mm; matrix 128 x 128; number of slices 4; FOV 400mm, b-values 0; 500 s/mm^2). BOLD MR images were obtained in breath-hold technique using a coronal multi-echo Gradient-Echo-Sequence (TR 280ms; 12 echoes from TE=5 to TE=49ms; increment 4ms; slice thickness 8mm; number of slices 5; matrix 192x192; FOV 430 mm). DCE-MRI was performed during free breathing with a Saturation-Recovery Turbo-FLASH sequence (TR 277 ms; TE 0.95 ms; slice thickness 8 mm, matrix 192 x 134; field of view 440 mm x 366 mm). Four slices were acquired within 1 s for a measurement time of 4 minutes. DCE-MRI was analyzed using retrospective respiratory triggering and a 2-compartment-model allowing for separation of perfusion (plasma flow: F_P, ml/100ml/min and plasma volume: V_P ml/100ml), permeability (extraction flow: F_E ml/100ml/min) and the extracellular volume (V_E), ml/100ml). Statistical analysis was performed with the Wilcoxon signed-rank test and Pearson´s correlation coefficient.

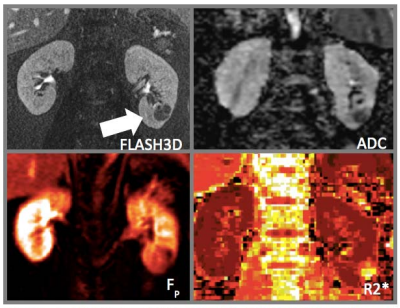

Figure 1: Hypovascularized papillary RCC with high R2* and low ADC.

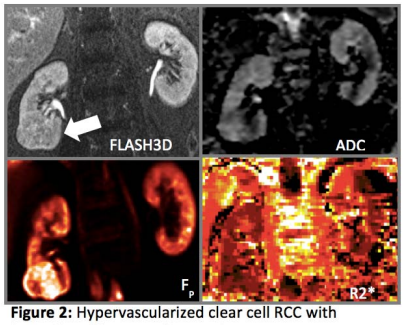

Figure 2: Hypervascularized clear cell RCC with low R2* and intermediate ADC.

Results: The ADC of clear cell RCC was slightly but not significantly higher than of papillary RCC (Table 1). The mean R2* of clear cell RCC was higher than of papillary subtypes (p = 0.1) (Figure 1 and Figure 2). F_P of clear cell RCC was significantly lower (p<0.05) than in papillary RCC and showed a high variability (range 22-495 ml/100ml/min). V_P of clear cell subtypes was also higher, but not significantly than in papillary RCC (p=0.06). There were no significant differences between clear cell and papillary subtypes regarding and F_E and V_E. The two completely necrotic tumors showed very low R2* (4.4 and 6.1 ms-1) and relatively high ADC (1.82 and 1. 72 mm^2/s). No relevant perfusion and permeability data could be derived from these tumors due to absent tumor enhancement. No significant correlation between ADC and R2* (r = 0.18) and between ADC and F_P (r = 0.34) or V_P (r = 0.42) was determined. There was a moderate, but significant correlation (p<0.01) between ADC and V_E (r = -0.57). Low R2* correlated moderately with high F_P (r = -0.52) and V_P (r = -0.73) (Figure 2). There was no relevant correlation between F_E and ADC (r = 0.24) or R2* (r = 0.18) and between V_E and R2* (r = 0.20).

Histology	ADC mm^2/s	R2* ms^{-1}	F_P ml/100ml/min	V_P ml/100ml	V_E ml/100ml	F_E ml/100ml/min
clear cell n = 12	1.45 ± 0.16	14.2 ± 7.5	189.1 ± 126.4	36.5 ± 23.9	9.2 ± 9.4	3.4 ± 5.4
papilllary n = 4	1.28 ± 0.15	21.7 ± 10.9	21.1 ± 16.4	10.01 ± 10.3	9.5 ± 1.7	1.8 ± 0.2
necrotic n = 2	1.76 ± 0.07	5.3 ± 1.2	n/a	n/a	n/a	n/a

Table 1: Overview of the functional MRI parameters.

Conclusion: A comprehensive multiparametrical MRI approach comprising DWI, BOLD and DCE-MRI is feasible for assessment of primary RCC. BOLD moderately correlates to perfusion parameters derived from DCE-MRI. ADC shows moderate correlation to the extracellular volume, but does not correlate to tumor oxygenation or perfusion as it provides mixed information on both perfusion and cellularity. Intravoxel incoherent motion analysis may resolve this ambiguity.

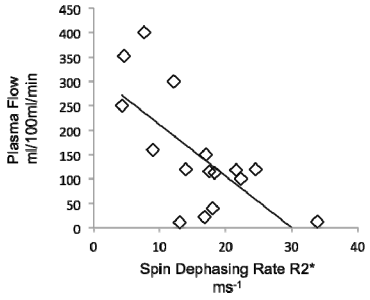

Figure 2: Exemplary Scatter Plot for Plasma Flow/R2* (r = -0.67).

References:
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