Quantitative Diffusion and Perfusion Parameters Discriminate High-Grade, Low-Grade, and Benign Targets at MRI-Ultrasound Fusion Biopsy

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Background: The feasibility of MRI-ultrasound fusion biopsies has been shown and validated. However, many targets still turn out benign at pathologic analysis. Although diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC) maps and dynamic contrast-enhanced (DCE) perfusion imaging improves sensitivity, the relative utility to discriminate benign from malignant disease, and low from high grade disease, has not been shown for this system.

Materials and Methods: With investigational review board approval, 102 consecutive men underwent MRI-ultrasound fusion targeted biopsy after magnetic resonance imaging at 3.0 T (Siemens Magnetom Trio) with external phased array coils only, including 3-dimensional T2-weighted imaging (T2WI) for lesion contouring (Siemens SPACE, TR 3800-5040 TE 101 ms, ETL 13, 1.5 mm slice thickness, no gap, matrix 256 x 205, 14 x 14 cm FOV) and DWI with ADC using low and high b-values (EPI; b = 0, 50, 150 and 400,600,1000 s/mm^2, TR 1600-2300 TE 75-90 ms, 5mm gap 1.65 mm, 256 x 154 matrix, FOV 35 x 26 cm) and full b-value (EPI; b = 0,100, 400, 800 s/mm^2; TR 3900 TE 60 ms; 3.6 mm slice; 160 x 130 matrix; FOV 26 x 26 cm) for comparison of a prior and newer protocol, and DCE using a k-space sharing technique (Siemens TWIST, TR/TE/FA 3.9/1.4 ms/12°, 3.6 mm reconstruction, matrix 160 x 160, 26 x 26 cm FOV, 70 acquisitions every 6 sec, 0.1 mg/kg gadopentetate dimeglumine [Magnevist, Bayer]). Perfusion pharmacokinetic modeling was accomplished on a CADvue workstation (iCAD Inc., Nashua, NH). ADC maps were generated by the scanner. All cases were reviewed by a single radiologist (DM). Regions of interest were chosen based on abnormal perfusion or diffusion but contoured on T2WI. These ROIs were used to extract average values for ADC and K^{trans}(transfer constant), k_{ep} (efflux rate), iAUGC (initial area under the gadolinium concentration curve for 30 seconds after enhancement), and EVF (extracellular extravascular volume fraction). The most conspicuous area was also identified and its average ADC recorded. Conventional time-intensity curve analysis, analogous to the breast MRI lexicon, was also recorded. For each target, the overall Gleason score (GS) grade is compared with the corresponding region of interest pharmacokinetic parameters, average ADC, size (on MRI), T2 suspicion score, and qualitative curve analysis. The student's t-test is used to determine whether there was a significant difference between benign and malignant targets dubbed p_{benign}, targets containing Gleason pattern 4 (high grade) and those that did not (low grade and benign) denoted $p_{high\ grade}$ and between low grade (Gleason pattern 3 only) and high grade (with Gleason pattern 4) targets, labeled $p_{low\ vs.\ high}$.

Findings: Successful imaging, pharmacokinetic analysis, standardized reporting, and fusion biopsies were accomplished in 89 patients for 175 targets. The averages and tests of significance are presented below:

Value	ADC_{low}	ADC_{high}	ADC_{full}	ADC_{worst}	K^{trans}	k_{ep}	EVF	iAUGC	Size	T2 score
Benign	1989	1157	1380	1053	0.282	0.928	0.346	5.274	0.980	3.04
Malignant	1834	1046	1247	941	0.477	1.339	0.370	6.742	1.149	3.15
GS 3+3	1790	1044	1273	910	0.484	1.242	0.404	6.237	1.126	3.06
GS>3+3	1912	1049	1201	993	0.466	1.511	0.310	7.639	1.189	3.29
p_{benign}	**0.009**	**<0.001**	**<0.001**	0.171	**<0.001**	**0.001**	0.124	**0.006**	**0.009**	0.136
$p_{high-grade}$	0.357	**0.033**	**0.002**	0.428	**0.050**	**0.005**	0.061	**0.006**	**0.046**	**0.046**
$pl_{ow\ vs.high}$	0.169	0.467	0.163	0.115	0.454	0.210	**0.002**	0.110	0.354	0.083

ADC values are given in square microns/second, or $\times 10^{-6}$ mm^2/s, and K^{trans} and k_{ep} in s^{-1}

Conclusion: The ADC based on the full range and upper range of b-values, and K^{trans} and k_{ep}, were able to discriminate benign from malignant tissue and specifically detect high grade disease. Interestingly, only EVF was able to discriminate high grade from low grade malignant disease. Additionally, the manually chosen ADC value did not reach statistical significance, suggesting that the average ADC for the entire ROI on T2WI should be used.