Multiparametric Prostate MRI - Correlation of Imaging Findings with MRI-Guided Biopsy Results

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TARGET AUDIENCE Radiologists interpreting prostate MRI, and those performing MRI-guided biopsies.

PURPOSE Prostate cancer (CaP) will affect 1 in 6 men in their lifetime. [1] The diagnosis of CaP is often made in through serial serum prostate-specific antigen (PSA) measurements, with trans-rectal ultrasound-guided (TRUS) biopsy for those patients with rising PSA. TRUS biopsy is limited by the nature of the procedure being performed "blinded" to the location of the cancer, which can result in false negative biopsies, or sampling of less aggressive regions of tumor, both of which can delay the necessary therapy. [2] Prostate MRI allows physicians to assess the entirety of the gland in a non-invasive manner. Although the multi-parametric MRI (mpMRI) evaluation of the prostate has been studied for several years now, [3-5] there is little data in the literature correlating mpMRI findings directly with histopathology. Our study is designed to correlate MRI-guided biopsy histopathology with pre-biopsy MRI parameters. With this data, we present a method that is reliable and easily implemented in clinical practice for evaluating lesions detected on mpMRI of the prostate.

METHODS Following IRB approval, a retrospective review was conducted of patients undergoing MRI-guided prostate biopsy at our institution. All included patients had pre-biopsy mpMRI on a Siemens 3-Tesla magnet with the following sequences: high-resolution tri-plane T2, axial DWI / ADC (b-values=0-2000, 3D multi-voxel spectroscopy and axial dynamic contrast-enhanced (DCE) T1 as previously described. [4] Pre-biopsy MRI was reviewed and each lesion that was biopsied was graded based on the following parameters: low T2 signal, diffusion restriction (high DWI and low ADC recorded separately), elevated choline spectroscopy peak (relative to the citrate peak), elevated perfusion on DCE, and malignant contrast washout on DCE (defined as greater than 20% washout from the peak). Each lesion was given a score of 0 if the parameter was negative, or 1 if the parameter was positive. An example of a lesion with all parameters positive is demonstrated in Figure 1. The data was tabulated and analyzed using the multiparametric statistical analysis presented below.

Table 1: Prediction Accuracy For The Individual Parameters

Method	TP	TN	FP	FN	Sn	Sp	PPV	NPV	Accuracy
DWI	7	30	1	10	0.41	0.97	0.88	0.75	0.77
ADC	17	22	9	0	1.00	0.71	0.65	1.00	0.81
Spectroscopy	8	21	10	9	0.47	0.68	0.44	0.70	0.60
Incr Perf	14	18	13	3	0.82	0.58	0.52	0.86	0.67
Malig Wash	6	29	2	11	0.35	0.94	0.75	0.72	0.73

Table 2: Prediction Accuracy For The Logistic Regression Models

Method	TP	TN	FP	FN	Sn	Sp	PPV	NPV	Accuracy
Model 1	15	25	6	2	0.88	0.81	0.71	0.93	0.83
Model 2	17	24	7	0	1.00	0.77	0.71	1.00	0.85

RESULTS Our dataset includes 14 patients with a total of 48 MRI-guided biopsied lesions. Average patient age = 63years (range 52-74). Average serum PSA value prior to biopsy = 8.31 ng/mL (range: 4.7-18.05ng/mL). Of the 14 patients, 10 (71.4%) had positive MRI-guided biopsies; of the 48 biopsies, 17 (35.4%) were positive. Many of the biopsies were intentionally performed on low-probability lesions to reinforce the integrity of the imaging paradigm.

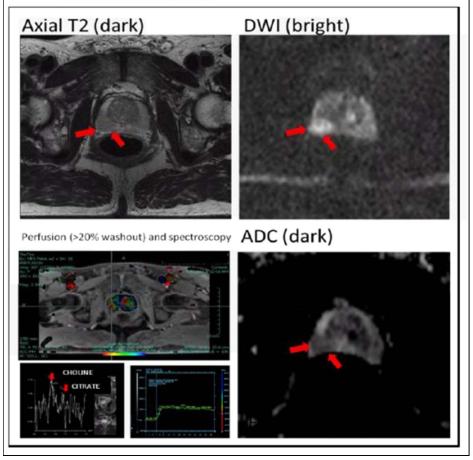
For the positive biopsies, the average Gleason score was 7.1 (range: 6-9). Four of the patients in the dataset had prior negative TRUS biopsies, two of whom wound up with a positive MRI-guided biopsy. One patient who had 6 prior negative TRUS biopsies had a lesion biopsied under MRI guidance that was Gleason 9, and another patient had 7 prior negative TRUS biopsies with a diagnosis of Gleason 7 prostate adenocarcinoma on MRI-guided biopsy.

Table 3: Scoring System for the Probability that a Lesion is CaP

Score	Probability of CaP
0	1.1298E-24
1	1.02159E-16
2	9.23745E-09
3	0.455121108
4	0.999999987
5	1
6	1

We computed the prediction accuracy for each of the five parameters (DWI, ADC, Elevated Choline Peaks on Spectroscopy, Increased Perfusion, and Malignant Washout). This includes the frequency of true positive (TP), true negative (TN), false negative (FN) and false positive (FP) along with the sensitivity, specificity, positive prediction value (PPV), negative predictive value (NPV) and the overall accuracy. The results are summarized in Table 1, showing that, when the parameters are analyzed individually, the ADC has the best performance in terms of sensitivity, NPV and Accuracy. We then considered two models to combine the outcome from the different parameters. Firstly, we combined all of the parameters with equal weighting into "Model 1". We fitted a logistic regression using Model 1 as a predictor of CaP. This resulted in a probability of CaP defined by the equation: $\text{Probability(CaP)} = \frac{1}{1+e^{5.734-2.194x}}$, where x = # of positive parameters for a lesion. The five parameters were then combined, using variable weighting to achieve maximum accuracy, resulting in "Model 2," defined by the equation: $\text{Probability(CaP)} = \frac{1}{1+e^{55.14-36.3[DWI]+19.54[ADC]+18.07[Cho]+17.94[Perf]+18.07[Wash]}}$, where each *[Parameter]* is given a value of 1 if positive, and 0 if negative. Table 2 demonstrates the accuracy of these models, showing Model 2 is superior to the ADC alone. With these probability models in mind, a scoring system for the parameters can be derived wherein a 1 is assigned for the ADC, Elevated Choline Peaks on Spectroscopy, Increased Perfusion, and Malignant Washout, and a 2 is assigned for a positive DWI. Any given lesion will therefore receive a score between 0-6. Using the Model 2 equation, we can see that a lesion with a score of 3 has a probability of being CaP of 22.6%, whereas a lesion with a score of 4 has a probability of being CaP of >99%. The probability for each of the possible scores is detailed in Table 3.

Figure 1: mpMRI of a Lesion with a Score of 6, MRI-guided biopsy proven prostate adenocarcinoma (Gleason 9)



DISCUSSION Even prior to statistical analysis of the data, our biopsy positivity rates exceed that of repeat TRUS biopsy.[6] Using the analysis presented, we have derived a statistically sound method of grading lesions on mpMRI to assist in the decision of which lesions should be biopsied. This scoring system allows a cutoff which can create an index of suspicion for each lesion, helping guide the decision of whether or not to biopsy. Using a cutoff score of 3 for maximum sensitivity, all of the cancers would have been biopsied and there would have been a 68.5% reduction in negative biopsies.

CONCLUSION Standardization of how mpMRI is interpreted is important as the technique becomes more widely available. The scoring system presented herein is both simplistic and robust in its utility for evaluating lesions detected on prostate MRI. This technique will allow for improved sensitivity and specificity in the detection of CaP. Patients with lesions scoring no higher than a 2 can be triaged into a low probability of cancer category, whereas those patients with a lesion scoring 3 or greater can be offered a directed biopsy, knowing the probability of cancer becomes significant with a score of 3 and very high with a score of 4 or more.

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