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Utility of Multiparametric MRI Suspicion Levels in Detecting Prostate Cancer

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Abstract

Purpose—To determine the utility of multiparametric-MRI (MP-MRI) in detecting prostate cancer (PCa), with specific focus on detecting higher-grade PCa.

Materials and Methods—Prospectively, 583 patients who underwent MP-MRI and subsequent prostate biopsy at a single institution were evaluated. On MP-MRI, lesions were identified and scored as low, moderate, or high suspicion for PCa based upon a validated scoring system. MR/US fusion-guided biopsies of MRI lesions in addition to systematic 12-core biopsies were performed. Correlations between the highest assigned MP-MRI suspicion score and presence of cancer and biopsy Gleason Score (bGS) on the first fusion biopsy session were assessed using univariate and multivariable logistic regression models. Sensitivity, specificity, NPV, and PPV were calculated and ROC curves were developed to assess the discriminative ability of MP-MRI as a diagnostic tool for various bGS cohorts.

Results—Significant correlations were found between age, PSA, prostate volume, and MP-MRI suspicion score and the presence of PCa ($p<0.0001$). On multivariable analyses controlling for age, PSA, and prostate volume, increasing MP-MRI suspicion was an independent prognosticator of PCa detection (OR=2.2, $p<0.0001$). Also, incremental increases in MP-MRI suspicion score demonstrated stronger associations with cancer detection in patients with Gleason ≥7 (OR=3.3, $p<0.001$) and Gleason ≥8 (OR=4.2, $p<0.0001$) PCa. Assessing MP-MRI as a diagnostic tool for all

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PCa, bGS≥7, and bGS≥8 separately via ROC analyses demonstrated increasing accuracy of MP-MRI for higher-grade disease (AUC=0.64, 0.69, and 0.72, respectively).

Conclusions—MP-MRI is a clinically useful modality to detect and characterize PCa, particularly in men with higher-grade disease.

INTRODUCTION

Prostate cancer (PCa) is the most common solid-organ malignancy among men in the western world and one of the leading causes of cancer-related mortality.[1] Multiple treatment options exist and their implementation depends highly upon clinical and biopsy-derived pathologic factors. Therefore, accurate pretreatment diagnosis is vital in dictating disease management and improving patient outcomes.

The key clinical parameters for predicting tumor aggressiveness and patient outcomes are cancer detection and Gleason score (bGS) assignment on prostate biopsy.[2] Furthermore, tumor grade, stage, and surrogate measures of volume often influence the treatment options entertained and ultimately employed. The current standard diagnosis of prostate cancer is determined via a systematic extended sextant TRUS guided biopsy prompted by either abnormal DRE or elevated serum PSA measurement. However, this biopsy regimen is limited in accurately predicting both presence and Gleason score in final pathologic outcomes found on radical prostatectomy specimens.[3–5]

As an alternative to a standard systematic biopsy, multiparametric prostate MRI (MP-MRI) used in conjunction with a MR/US fusion guided biopsy platform has demonstrated improved PCa detection and localization.[6–9] Herein, we aim to determine the utility of MP-MRI in detecting the presence of all PCa and specifically cases of men harboring higher-grade PCa.

METHODS

Patient Selection and Data Collection

Patients were enrolled under an institutional review board approved, prospective trial assessing MRI/US fusion guided prostate biopsy with electromagnetic tracking at the National Cancer Institute of the National Institutes of Health between August 2007 and August 2012. Data was collected and stored in a secure database organized by subject numbers which were assigned to patients after obtaining their written informed consent understanding the research protocol and implications of prostate cancer screening.

A total of 810 cases of MP-MRI were performed over this time period, of which 671 cases of MP-MRI identified lesions suspicious for PCa and were followed by MR/US fusion guided prostate biopsies. This series of biopsy cases represents data on 583 patients, including 70 patients with multiple sessions of MP-MRI and subsequent fusion biopsies on an active surveillance arm of the study. For patients with multiple sessions of MP-MRI and MR/US fusion guided prostate biopsies on active surveillance, only the first imaging and paired biopsy session were used for analysis (Figure 1). Specifically, patient demographics

and prebiopsy PSA, prostate size, number of MP-MRI lesions, and MP-MRI cancer suspicion score per lesion were collected. Biopsy pathologic findings were also evaluated.

Imaging and Biopsy Protocol

All patients initially underwent a diagnostic MP-MRI of the prostate, including tri-planar T2-weighted (T2W), dynamic contrast-enhanced (DCE), diffusion-weighted imaging (DWI), and MR spectroscopy sequences performed on a 3.0T MRI scanner (Achieva, Philips Healthcare, Best, The Netherlands) with a 16-channel cardiac surface coil (SENSE, Philips Healthcare) positioned over the pelvis and an endorectal coil (BPX-30, Medrad, Pittsburgh, Pennsylvania), as previously described.[10,11] These diagnostic MP-MRI studies underwent blinded centralized radiological evaluation with identification of lesions and assignment of prostate cancer suspicion level (low, moderate, or high) to each lesion using a validated scoring system as previously reported (Figure 2).[12] In cases with limitations on image acquisition quality, secondary to artifacts arising from metal prostheses, body habitus, and motion artifact, data from diagnostic parameters were used to assign a suspicion score, paralleling real-world limitations encountered with MRI.

Patients included in this study all had lesions suspicious for PCa on MP-MRI and underwent prostate biopsy as previously described in detail.[6] Irrespective of the suspicion level assigned to the lesions identified on MP-MRI, patients were offered participation in the MR/US fusion guided prostate biopsy protocol. Enrollment was also based upon informed consent specific to the procedure, thus excluding 4 patients with positive findings on MP-MRI who were not biopsied on the MR/US fusion guided prostate biopsy protocol (Figure 1).

A systematic extended sextant 12-core TRUS guided biopsy by a practitioner blinded to the MRI target lesions was performed, as well as targeted biopsies using an office-based MR/US fusion guided biopsy platform that superimposed real-time TRUS with MP-MRI findings to identify and biopsy target lesions. All MRI target lesions were sampled with at least 2 core biopsies, in the axial and sagittal planes for each target. All biopsy pathology was reviewed by a single genitourinary pathologist.

Data Analysis

Univariate and multivariate analysis were performed to test for an association between MP-MRI suspicion level and detection of all prostate cancer as well as detection of higher grade prostate cancer: bGS ≥7 and bGS ≥8 cancers. Logistic regression models were utilized for these univariate and multivariable analyses.

Sensitivity, specificity, negative predictive value, and positive predictive value were determined for the detection of all prostate cancer, Gleason ≥7 cancer, and Gleason ≥8 cancer. Receiver operating characteristic (ROC) curves were calculated to determine the discriminative ability of MP-MRI as a diagnostic instrument and area under the curve (AUC) was calculated for each ROC curve. To test for statistical significance between the AUC for two curves, DeLong's test for two ROC curves was utilized. R (http://www.r-project.org/) was utilized for the ROC analysis with the pROC package. For all remaining statistical analysis, the JMP Pro 10.0 (SAS Institute Inc, 2012) was utilized.

RESULTS

Table 1 shows the demographic characteristics of the study population. The mean age was 61.3 years. Of note, 59% of cancers were Gleason 7 or higher, and the mean PSA in the population was 9.9 ng/mL. A majority of patients (63.5%) carried a moderate suspicion prostate lesion as the highest MP-MRI PCa suspicion score assigned. Patients underwent MR/US fusion guided prostate biopsy a median of 39 days following MP-MRI.

Upon univariate analysis: age, PSA, prostate volume, and MP-MRI suspicion score were all significantly associated with biopsy detection of PCa. When controlling for age, PSA, and prostate volume, MP-MRI suspicion remained significantly associated with the detection of PCa with an odds ratio (OR) of 2.2 for each increase in MP-MRI suspicion level (Table 2). A similar analysis was repeated for the detection of Gleason score ≥7 cancers with an OR of 3.3 per increase in MP-MRI suspicion score ($p<0.0001$) when controlling for age, PSA, and prostate volume. For the detection of Gleason ≥8 cancers, the multivariable analysis demonstrated a stronger association with MP-MRI suspicion score (OR 4.2, $p<0.0001$).

Sensitivity, specificity, negative predictive values, and positive predictive values were determined for the detection of all prostate cancer, Gleason ≥7 cancers, and Gleason ≥8 cancers. Two possible cutoffs exist with MP-MRI suspicion to determine a negative versus positive test result: one between low and moderate suspicion scores and another between moderate and high suspicion score assignments. Table 3 demonstrates the performance of MP-MRI for the detection of any PCa and also for each of the aforementioned subsets with only higher-grade cancers. Although high sensitivity and specificity could be achieved with MP-MRI, no optimal cutoff existed such that the diagnostic study had both high sensitivity and specificity concurrently. For the detection of all cancer, the test had an 87% sensitivity at the lower cutoff and 94% specificity at the higher cutoff. These were however associated with 30% specificity at the low cutoff and 24% sensitivity at the high cutoff, respectively. For the detection of more aggressive disease, MP-MRI performed better, with 94% and 98% sensitivity at the low cutoff for patients with Gleason ≥7 and Gleason ≥8 cancers, respectively. These improved levels of sensitivity were again limited by low associated levels of specificity. Additionally, NPV for detection of Gleason ≥8 PCa was increased to 91% for both the low and high cutoff.

To more rigorously assess this observed trend in improved discriminant capabilities of MP-MRI for more aggressive cancer, ROC curves were plotted for MP-MRI detection of all PCa, Gleason score ≥7 cancer, and Gleason score ≥8 cancer (Figure 3). Subset analysis of (1) 320 patients who had prior negative systematic 12-core extended sextant biopsies prior to referral for MP-MRI and MR/US fusion guided prostate biopsies and (2) 70 patients on active surveillance at our institution demonstrated no statistically significant difference of the AUCs calculated for the detection of Gleason 6, ≥7, and ≥8 disease compared to that of the entire 583 patient population.

The AUC increased as the cancer grade increased, suggesting an improved performance of this diagnostic modality for the detection of higher grade cancers. The difference between the AUC for the detection of all cancer and detection of Gleason score ≥7 cancers

approached statistical significance (p=0.052) and for Gleason score ≥8 cancers was statistically significant (p=0.01).

DISCUSSION

The process of diagnosing of prostate cancer has evolved dramatically since the discovery of PSA and implementation of various PCa screening protocols. There has been a well-recognized stage migration toward organ-confined disease since the implementation of PSA-based screening.[13] The vast majority of men currently diagnosed with PCa in the United States are given this diagnosis based upon prostate biopsy results prompted by an elevated serum PSA assessment or abnormal DRE, cT1c or cT2 disease, respectively.[14] In the PSA era, there was been a notable reduction in PCa related mortality, however, given the dramatic increase in PCa diagnoses and subsequent treatment, it is suggested that a significant proportion of men diagnosed with PCa are overtreated.[15] This underscores the limited sensitivity and specificity of PSA and DRE, the diagnostic parameters most commonly implemented in screening protocols, in identifying and delineating smaller, more indolent, lower risk cancers compared to larger, more aggressive, higher risk cancers among the population of patients harboring organ-confined disease.[5] In response to the recent recommendations against PSA screening for prostate cancer rendered by the US Preventative Services Task Force, primary care physicians and urologists have investigated different schema for PCa screening with the goal of targeting more clinically-significant cancers and minimizing the overdiagnosis and overtreatment resulting from PSA-based screening.[16,17] Clearly, there is a major clinical need for a non-invasive method of characterizing PCa and detecting especially higher grade PCa.

Prior to detailed anatomical and functional imaging of the prostate with MRI, the only quantitative measures of PCa tumor volume were invasive in nature. These included radical prostatectomy specimen assessment and surrogate measures of tumor burden ascertained by the number of biopsy cores and percent of biopsy cores involved with cancer, which are not consistently representative of tumor size and burden on final pathology.[18,19] Prior reported works have demonstrated the capability of MRI in identifying lesions harboring PCa. Technological advancements can now be used to fuse diagnostic MP-MRI to real-time TRUS in turn allowing for identification and localization of suspicious lesions during the prostate biopsy procedure. In this manner, biopsies targeting lesions observed on MP-MRI have been shown to provide reproducible correlation between visualization of suspicious lesions and true PCa on both biopsy and radical prostatectomy whole mount specimens.[6,7] In the current investigation, we have expanded upon an earlier experience reported by Pinto and colleagues whereby they reported the initial 101 patients included in the current larger patient population with concordant PCa detection findings and stronger associations with higher grade disease.[6] We have also shown data supporting other prior reports, confirming the strong correlation between MP-MRI derived suspicion and pathologic detection of PCa.

The highlight of our investigation is the value of the MP-MRI suspicion score assignment in detecting PCa with a much more significant association in patients with higher-grade disease. In the multivariable logistic regression model correcting for prebiopsy parameters including serum PSA level, patient age, and total prostate volume, the highest lesional

suspicion score seen on MP-MRI in any given patient was more predictive of cancer detection for the subsets of patients harboring higher-grade cancers. The importance of a novel, improved screening modality is emphasized with the declining widespread use of routine PSA screening in the setting of the US Preventative Services Task Force grade “D” recommendation and the continued epidemiological dilemma of prostate cancer bearing such high incidence and mortality. As an independent predictor of cancer detection, MR imaging findings can potentially be coupled with PSA or other prognostic parameters to increase the screening specificity for clinically-significant prostate cancers which was lacking in the PSA screening protocols. If applied wisely, this can conceivably reduce overdiagnosis of low-grade cancers while focusing treatment on men with more aggressive forms of the disease.

MP-MRI has been under investigation for differentiation of low-risk versus higher-risk PCa by several groups of investigators.[20–22] MRI provides an anatomical assessment, which is not provided with serum PSA assessment and is most crudely assessed with DRE only in larger, peripheral tumors in a specific topographical location. Evaluation of lesional volume and location within the overall prostate gland allows for evaluation of overall tumor burden and likelihood of local spread, which have been shown to be associated with PCa aggressiveness and future prognosis.[22] With this additional information, the use of MP-MRI may aid in identifying patients who can safely pursue active surveillance versus those who harbor disease that is incompletely evaluated by current standards of DRE, PSA assessment, and systematic TRUS guided biopsy sampling. This has been shown specifically for lesions in specific zones of the prostate where biopsy undersampling can miss occult malignant lesions, including distal apical and anterior located PCa lesions.[23,24]

In addition to the anatomic localization on MRI allowing for identification and targeted biopsy of often occult lesions, our data demonstrates that MP-MRI provides an even stronger diagnostic yield in patient harboring higher-grade disease. Together with the anatomical definition of suspicious lesional size and the discriminative accuracy of detecting PCa, specifically in men with higher-grade disease, MP-MRI provides a multifaceted diagnostic tool that potentially culls out patients with clinically significant cancer who would not fit either Epstein or Stamey criteria for low tumor burden, low-grade cancer deemed to be clinically more indolent.[18,25] This can ultimately provide a basis for individualized patient care if data from prebiopsy MRI can direct management and treatment counseling.

A potential limitation of this study is patient selection bias. Specifically, the study population represents a relatively high proportion of patients who were found to have a Gleason score ≥7 as well as a high mean serum PSA which may limit its translational applicability to all populations. These skewed patient characteristics compared with the American population of men at large who are currently diagnosed with prostate cancer are likely reflective of the referral pattern to the NCI. Many patients in this study population have undergone prior negative biopsies despite elevated PSA assessments or had low grade, low volume disease consistent with active surveillance candidacy by standard screening methods thought not to match the PSA levels prior to referral for a diagnostic MP-MRI and MR/US fusion guided biopsy. In both of these patient cohorts enriched for in our study

population, the performance characteristics of the MP-MRI were equivalent, however, we do not have data for the control group of patients for whom the MP-MRI demonstrated no lesions since these patients could not enroll in our MR/US fusion guided biopsy protocol.

Also, another limitation is that complete data on lesion-based findings for those lesions confirmed to bear PCa, including lesional volume and localization have only been rigorously evaluated for the subset of patients who have undergone radical prostatectomy at our institution.[7,26] Based on the findings of this study, future prospective PCa screening protocols are needed to evaluate the benefit of MP-MRI as an independent modality, as well as MRI coupled with other screening parameters including PSA and measures of PSA dynamics in detecting clinically-significant cancers.

CONCLUSION

Lesions identified by MP-MRI demonstrate a high correlation with the presence of prostate cancer on MR/US fusion guided prostate biopsies. Furthermore, levels of pre-biopsy radiographic suspicion demonstrated increasingly higher ability to detect higher-grade disease. MP-MRI is a clinically useful modality in the evaluation and detection of prostate cancer, specifically for patients harboring higher-grade disease.

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References

1. Siegel R, Naishadham D, Jemal A. Cancer statistics, 2012. CA Cancer J Clin. 62:10.2012; [PubMed: 22237781]
2. Egevad L, Granfors T, Karlberg L, Bergh A, Stattin P. Prognostic value of the Gleason score in prostate cancer. BJU Int. 89:538.2002; [PubMed: 11942960]
3. Belas O, Hupertan V, Comperat E, Renard-Penna R, Mozer P, Bitker MO, et al. Low accuracy of routine ultrasound-guided systematic 12-core biopsies in prostate tumor mapping. Can J Urol. 19:6366.2012; [PubMed: 22892260]
4. Kvale R, Moller B, Wahlqvist R, Fossa SD, Berner A, Busch C, et al. Concordance between Gleason scores of needle biopsies and radical prostatectomy specimens: a population-based study. BJU Int. 103:1647.2009; [PubMed: 19154461]
5. Conti SL, Dall'era M, Fradet V, Cowan JE, Simko J, Carroll PR. Pathological outcomes of candidates for active surveillance of prostate cancer. J Urol. 181:1628.2009; [PubMed: 19233388]
6. Pinto PA, Chung PH, Rastinehad AR, Baccala AA Jr, Kruecker J, Benjamin CJ, et al. Magnetic resonance imaging/ultrasound fusion guided prostate biopsy improves cancer detection following transrectal ultrasound biopsy and correlates with multiparametric magnetic resonance imaging. J Urol. 186:1281.2011; [PubMed: 21849184]
7. Turkbey B, Mani H, Shah V, Rastinehad AR, Bernardo M, Pohida T, et al. Multiparametric 3T prostate magnetic resonance imaging to detect cancer: histopathological correlation using prostatectomy specimens processed in customized magnetic resonance imaging based molds. J Urol. 186:1818.2011; [PubMed: 21944089]

8. Sonn GA, Natarajan S, Margolis DJ, MacAiran M, Lieu P, Huang J, et al. Targeted biopsy in the detection of prostate cancer using an office based magnetic resonance ultrasound fusion device. J Urol. 189:86.2013; [PubMed: 23158413]
9. Hadaschik BA, Kuru TH, Tulea C, Rieker P, Popeneciu IV, Simpfendorfer T, et al. A novel stereotactic prostate biopsy system integrating pre-interventional magnetic resonance imaging and live ultrasound fusion. J Urol. 186:2214.2011; [PubMed: 22014798]
10. Vourganti S, Rastinehad A, Yerram NK, Nix J, Volkin D, Hoang A, et al. Multiparametric magnetic resonance imaging and ultrasound fusion biopsy detect prostate cancer in patients with prior negative transrectal ultrasound biopsies. J Urol. 188:2152.2012; [PubMed: 23083875]
11. Turkbey B, Pinto PA, Mani H, Bernardo M, Pang Y, McKinney YL, et al. Prostate cancer: value of multiparametric MR imaging at 3 T for detection–histopathologic correlation. Radiology. 255:89.2010; [PubMed: 20308447]
12. Turkbey B, Mani H, Aras O, Ho J, Hoang A, Rastinehad AR, et al. Prostate Cancer: Can Multiparametric MR Imaging Help Identify Patients Who Are Candidates for Active Surveillance? Radiology. 2013
13. Hernandez J, Thompson IM. Prostate-specific antigen: a review of the validation of the most commonly used cancer biomarker. Cancer. 101:894.2004; [PubMed: 15329895]
14. Derweesh IH, Kupelian PA, Zippe C, Levin HS, Brainard J, Magi-Galluzzi C, et al. Continuing trends in pathological stage migration in radical prostatectomy specimens. Urol Oncol. 22:300.2004; [PubMed: 15283887]
15. Etzioni R, Tsodikov A, Mariotto A, Szabo A, Falcon S, Wegelin J, et al. Quantifying the role of PSA screening in the US prostate cancer mortality decline. Cancer Causes Control. 19:175.2008; [PubMed: 18027095]
16. US Preventive Services Task Force. Screening for Prostate Cancer: US Preventive Services Task Force recommendation statement: draft: summar of recommendation and evidence. Jul 10.2013
17. Moyer VA. Screening for prostate cancer: U.S. Preventive Services Task Force recommendation statement. Ann Intern Med. 157:120.2012; [PubMed: 22801674]
18. Epstein JI, Walsh PC, Carmichael M, Brendler CB. Pathologic and clinical findings to predict tumor extent of nonpalpable (stage T1c) prostate cancer. JAMA. 271:368.1994; [PubMed: 7506797]
19. Iremashvili V, Pelaez L, Manoharan M, Jorda M, Rosenberg DL, Soloway MS. Pathologic prostate cancer characteristics in patients eligible for active surveillance: a head-to-head comparison of contemporary protocols. Eur Urol. 62:462.2012; [PubMed: 22445138]
20. Rastinehad AR, Baccala AA Jr, Chung PH, Proano JM, Kruecker J, Xu S, et al. D'Amico risk stratification correlates with degree of suspicion of prostate cancer on multiparametric magnetic resonance imaging. J Urol. 185:815.2011; [PubMed: 21239006]
21. Vargas HA, Akin O, Afaq A, Goldman D, Zheng J, Moskowitz CS, et al. Magnetic resonance imaging for predicting prostate biopsy findings in patients considered for active surveillance of clinically low risk prostate cancer. J Urol. 188:1732.2012; [PubMed: 23017866]
22. Zhang J, Hricak H, Shukla-Dave A, Akin O, Ishill NM, Carlino LJ, et al. Clinical stage T1c prostate cancer: evaluation with endorectal MR imaging and MR spectroscopic imaging. Radiology. 253:425.2009; [PubMed: 19864529]
23. Nix JW, Turkbey B, Hoang A, Volkin D, Yerram N, Chua C, et al. Very distal apical prostate tumours: identification on multiparametric MRI at 3 Tesla. BJU Int. 110:E694.2012; [PubMed: 23035719]
24. Ouzzane A, Puech P, Lemaitre L, Leroy X, Nevoux P, Betrouni N, et al. Combined multiparametric MRI and targeted biopsies improve anterior prostate cancer detection, staging, and grading. Urology. 78:1356.2011; [PubMed: 21840577]
25. Stamey TA, Freiha FS, McNeal JE, Redwine EA, Whittemore AS, Schmid HP. Localized prostate cancer. Relationship of tumor volume to clinical significance for treatment of prostate cancer. Cancer. 71:933.1993; [PubMed: 7679045]
26. Turkbey B, Mani H, Aras O, Rastinehad AR, Shah V, Bernardo M, et al. Correlation of magnetic resonance imaging tumor volume with histopathology. J Urol. 188:1157.2012; [PubMed: 22901591]

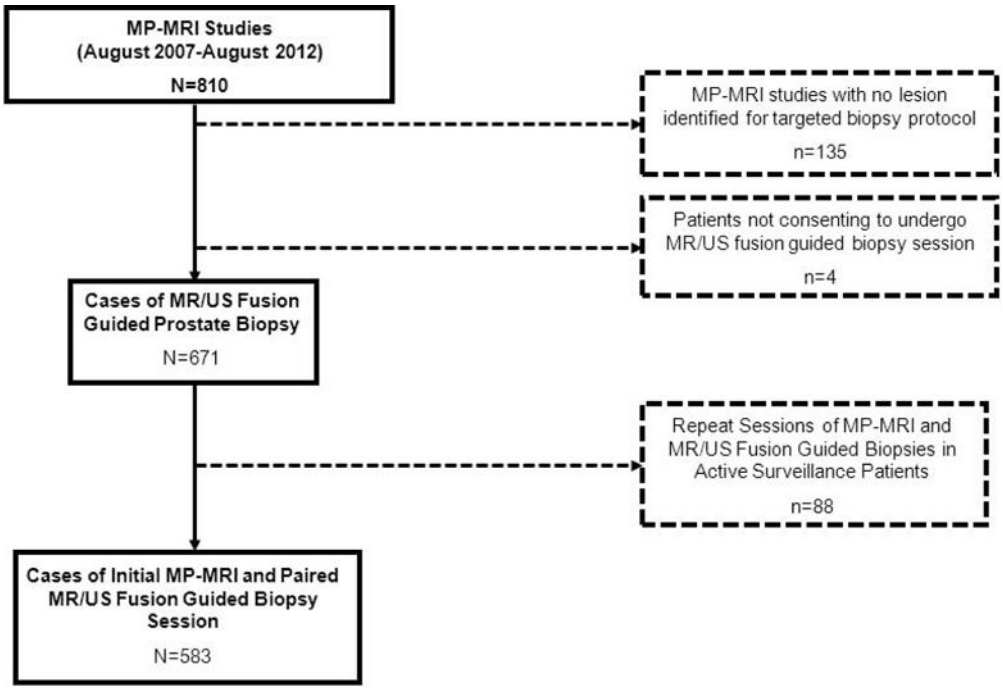

Figure 1.

Diagram outlining inclusion and exclusion criteria for MP-MRI and MR/US fusion guided biopsy sessions included in data analysis.

Findings of MRI Sequence				mpMRI Suspicion Level
T2W MRI	ADC map of DW MRI	MR Spectroscopy	DCE MRI	
-	-	-	-	Negative
+	-	-	-	Low
+	+	-	-	Low
-	+	-	-	Low
-	-	+	-	Low
-	-	-	+	Low
+	-	+	-	Moderate
+	-	-	+	Moderate
-	+	+	-	Moderate
-	+	-	+	Moderate
+	+	+	-	Moderate
+	+	-	+	Moderate
-	-	+	+	Moderate
+	+	+	+	High

Figure 2.
Lesion based MP-MRI cancer suspicion scoring system.

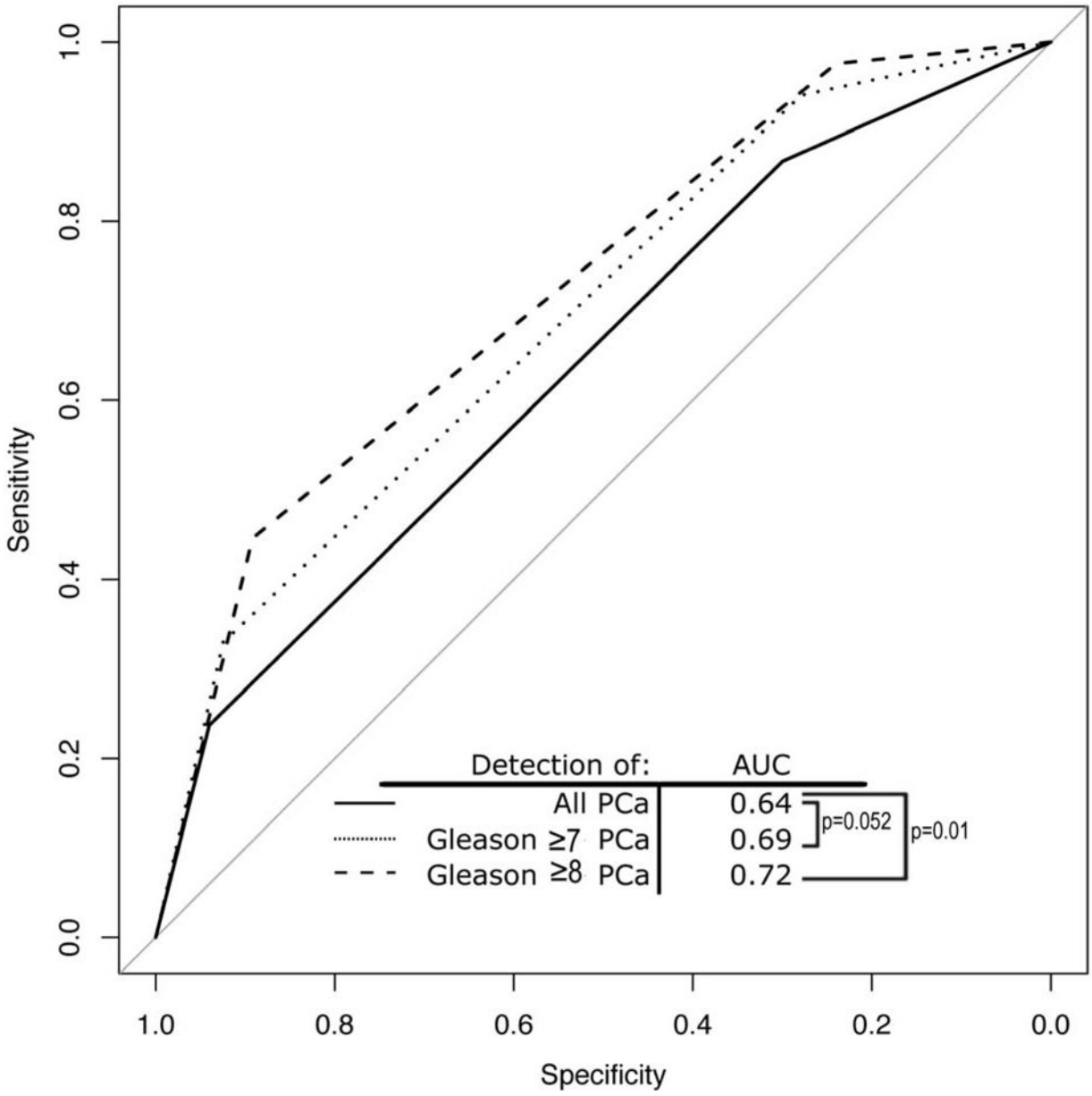

Figure 3.
ROC analysis of MP-MRI prediction of all, Gleason ≥7, and Gleason ≥8 prostate cancer found on biopsy.

Table 1

Patient demographics, distribution of MP-MRI assigned prostate cancer suspicion scores, and summary of biopsy findings.

Number of Men	583
Age (years)	61.3 ± 8.4
PSA (ng/ml)	9.9 ± 13.1
Cancer Suspicion Score on MP-MRI	
Low	122 (20.9%)
Moderate	370 (63.5%)
High	91 (15.6%)
Number of Men with PCa on Biopsy	316
Gleason 6	131 (41.4%)
Gleason 7	102 (32.3%)
Gleason ≥8	83 (26.3%)

Table 2

Association of pre-biopsy parameters with prostate cancer detection on prostate biopsy.

	All Prostate Cancer				Gleason score ≥7				Gleason score ≥8			
	Univariate		Multivariable		Univariate		Multivariable		Univariate		Multivariable	
	O.R.	***p-value***	**O.R.**	***p-value***	**O.R.**	***p-value***	**O.R**	***p-value***	**O.R.**	***p-value***	**O.R**	***p-value***
Age (per 10 years)	1.26 [**1.00,1.50**]	0.03	1.37 [**1.01,1.62**]	0.01	1.53 [**1.21,1.94**]	0.0002	1.7 [**1.28,2.26**]	0.0003	1.9 [**1.35,2.59**]	<0.0001	2.0 [**1.35,2.90**]	*0.0004*
PSA (per ng/ml)	1.02 [**1.01,1.05**]	0.003	1.03 [**1.01,1.06**]	0.004	1.05 [**1.03,1.07**]	<0.0001	1.08 [**1.05,1.11**]	<0.0001	1.04 [**1.02,1.06**]	<0.0001	1.04 [**1.02,1.07**]	*0.0002*
Prostate volume (per 10cc)	0.82 [**0.76,0.87**]	<0.0001	0.78 [**0.73,0.85**]	<0.0001	0.79 [**0.72,0.86**]	<0.0001	0.70 [**0.62,0.77**]	<0 0001	0.84 [**0.74,0.93**]	0.0003	0.78 [**0.68,0.88**]	*<0.0001*
MRI suspicion score (per suspicion increase)	2.8 [**2.08,3.84**]	<0.0001	2.2 [**1.59,3.17**]	<0.0001	4.6 [**3.20,6.64**]	<0.0001	3.3 [**2.21,5.10**]	<0.0001	5.5 [**3.53,8.72**]	<0.0001	4.2 [**2.52,7.13**]	*<0.0001*

Table 3

Sensitivity, specificity, positive predictive value, and negative predictive value of MP-MRI assigned prostate cancer suspicion score for cancer detection.

		Cutoff between low and moderate suspicion MP-MRI	Cutoff between moderate and high suspicion on MP-MRI
All PCa	sensitivity	0.87	0.24
	specificity	0.30	0.94
	PPV	0.59	0.82
	NPV	0.66	0.51
Gleason ≥7 PCa	sensitivity	0.94	0.33
	specificity	0.28	0.92
	PPV	0.38	0.67
	NPV	0.91	0.75
Gleason ≥8 PCa	sensitivity	0.98	0.45
	specificity	0.24	0.89
	PPV	0.18	0.41
	NPV	0.91	0.91