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Diagnostic value of biparametric magnetic resonance imaging (MRI) as an adjunct to prostate-specific antigen (PSA)-based detection of prostate cancer in men without prior biopsies

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Abstract

Objectives—To determine the diagnostic yield of analysing biparametric (T2- and diffusion-weighted) magnetic resonance imaging (B-MRI) for prostate cancer detection compared with standard digital rectal examination (DRE) and prostate-specific antigen (PSA)-based screening.

Patients and Methods—Review of patients who were enrolled in a trial to undergo multiparametric-prostate (MP)-MRI and MR/ultrasound fusion-guided prostate biopsy at our institution identified 143 men who underwent MP-MRI in addition to standard DRE and PSA-based prostate cancer screening before any prostate biopsy. Patient demographics, DRE staging, PSA level, PSA density (PSAD), and B-MRI findings were assessed for association with prostate cancer detection on biopsy.

Results—Men with detected prostate cancer tended to be older, with a higher PSA level, higher PSAD, and more screen-positive lesions (SPL) on B-MRI. B-MRI performed well for the detection of prostate cancer with an area under the curve (AUC) of 0.80 (compared with 0.66 and 0.74 for PSA level and PSAD, respectively). We derived combined PSA and MRI-based formulas

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Conflicts of Interest
None declared.

for detection of prostate cancer with optimised thresholds. (i) for PSA and B-MRI: $\text{PSA level} + 6 \times (\text{the number of SPL}) > 14$ and (ii) for PSAD and B-MRI: $14 \times (\text{PSAD}) + (\text{the number of SPL}) > 4.25$. AUC for equations 1 and 2 were 0.83 and 0.87 and overall accuracy of prostate cancer detection was 79% in both models.

Conclusions—The number of lesions positive on B-MRI outperforms PSA alone in detection of prostate cancer. Furthermore, this imaging criteria coupled as an adjunct with PSA level and PSAD, provides even more accuracy in detecting clinically significant prostate cancer.

Keywords

PSA; PSA density; prostate cancer detection; MRI

Introduction

Prostate cancer is the most common solid-organ malignancy in American men and is responsible for an estimated 10% of cancer-related mortality in the USA [1]. Most prostate cancers diagnosed today are detected on biopsies prompted by elevated PSA levels [2]. Recently, the USA Preventive Services Task Force has recommended against widespread PSA screening based upon inconclusive data from large screening trials regarding survival benefit [3–6]. Elevated PSA values often lead to random biopsies that too often identify low-volume, low-grade disease resulting in overtreatment. Multiparametric-prostate-MRI (MP-MRI) has emerged as an anatomical and functional imaging method that offers diagnostic accuracy in detecting, localising, and staging prostate cancer [7–9]. MP-MRI typically consists of a T2-weighted (T2W) and diffusion-weighted imaging (DWI), as well as dynamic contrast-enhanced MRI and in some cases, MR spectroscopy. Limitations of MP-MRI for implementation as an adjunct tool for prostate cancer screening include its cost and the time required to complete the study including the placement of an endorectal coil and the use of gadolinium-based contrast agents requiring i.v. access. To overcome these limitations, it has been suggested that a limited MP-MRI study incorporating only non-contrast T2W and DWI series could potentially provide a diagnostic scan in ≈ 15 min at a reduced cost. In the present study, we investigated the diagnostic yield of using this biparametric-MRI (B-MRI) approach for prostate cancer detection compared with and coupled with standard PSA-based screening practices in patients who had suspicion of prostate cancer.

Patients and Methods

Retrospective review of 696 patients who enrolled in a protocol to undergo MP-MRI and subsequent MR/ultrasound (US) fusion-guided prostate biopsy at the National Cancer Institute between August 2007 and December 2012 identified 143 patients who had not undergone any prior prostate biopsy before entry into this imaging and biopsy protocol. These patients were all referred for entry into this protocol based on the clinical suspicion of prostate cancer derived from either elevated PSA levels or abnormal findings on DRE. All patients enrolled had a serum PSA assessment, DRE, and underwent prostate imaging with MP-MRI as previously described [10]. If lesions were suspicious for prostate cancer on MP-MRI, patients subsequently underwent MR/US fusion-guided biopsy using an office-based

platform (UroNav, InVivo Corp) to target biopsies to suspicious lesions in addition to performing a systematic 12-core extended sextant biopsy at the same session.

Data Collection and Analyses

MP-MRI identified suspicious lesions based on well-established characteristics on each imaging parameter [11]. For the purposes of this retrospective study, patients with lesions visible and suspicious on both T2W and DWI MRI sequences were considered B-MRI 'screen-positive' lesions (SPL). Patient demographics, imaging, and pathology data correlating to the targets found only on B-MRI in addition to the systematic 12-core biopsy were collected and stored in a secure database.

Statistical comparisons of categorical and continuous variables were performed using Fisher's exact test and paired, two-tailed Student's *t*-tests, respectively. Sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV) were calculated for the detection of prostate cancer based on thresholds of PSA level of >4 ng/mL, PSA density (PSAD) of >0.15 ng/mL/mL, and number of B-MRI SPL >1. Receiver operating characteristic (ROC) curves were calculated to determine the discriminative ability of pre-biopsy variables including PSA level, PSAD, number of target lesions, and number of SPL as diagnostic instruments. The 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 was used. R(<http://www.r-project.org/>) was used for the ROC analysis with the pROC package. For all remaining statistical analysis, the JMP Pro 10.0 (SAS Institute Inc, 2012, Cary NC) was used.

Composite equations for models combining PSA level with the number of SPL, as well as combining PSAD with the number of SPL, were derived using the parameters generated by the logistic regression. Specifically, a generalised linear model of the form: $\ln(p/(1-p)) = Ax + By + C$ where A, B, and C are the constants derived from the logistic regression analysis and p is the probability of prostate cancer. This formula was re-written as $(\ln(p/(1-p)) - C)/A = x + B/A * y$ where x and y are two of the three PSA level, PSAD, and number of SPL as appropriate. The optimal threshold was determined by the maximal point of sensitivity and specificity. Decision curve analysis was also used to compare the net benefit of the different logistic regression models generated using R code made available by A.Vickers (<http://www.mskcc.org/research/epidemiology-biostatistics/health-outcomes/decision-curve-analysis-0>) [12].

Results

Among the 143 patients analysed with no prostate biopsies before MP-MRI and MR/US fusion-guided biopsy, the mean (SD, range) age was 60.7 (7.7, 41–80) years and the mean (SD, range) PSA level before biopsy was 6.8 (6.5, 0.1–51.1) ng/mL. Complete demographic information is given in Table 1. Men with detected prostate cancer tended to be older, with a higher PSA level, higher PSAD, smaller prostate volume, positive DRE findings, increased bilaterality of suspicious lesions, increased number of total MRI lesions, and increased the number of SPL identified on B-MRI (Table 1). ROC curves were generated for the use of

PSA level, PSAD, total lesions identified, and the number of SPL on B-MRI. The AUC for these tests ranged from 0.66 for PSA level alone to 0.80 for the number of SPL (Fig. 1). There was a statistically significant difference between the AUCs for PSA level and the number of SPL ($P = 0.02$) but not for AUCs for PSAD and the number of SPL ($P = 0.20$).

To further improve the utility of MRI in this pre-screened population, the combined use of the number of SPL with PSA level and PSAD was examined. The ROC curves for the combined use of PSA level with the number of SPL and PSAD with the number of SPL are shown in Fig. 2A. Combined use of PSA level and PSAD with the number of SPL improved the AUC to 0.83 and 0.87, respectively. The optimal threshold for these combined models were determined by maximising the Youden index (sensitivity + specificity) (Fig. 2B). For the B-MRI SPL the optimal threshold was >1 and considered a positive test. For the PSA and MRI combined models, the following equations were derived based on the logistic regression equation to maximise sensitivity and specificity for prostate cancer detection:

- For PSA level with the number of SPL: $\text{PSA level} + 6 \times (\text{the number of SPL}) > 14$
- For PSAD with the number of SPL: $14 \times (\text{PSAD}) + (\text{the number of SPL}) > 4.25$

The sensitivity, specificity, PPV, NPV, and overall accuracy of PSA level, PSAD, B-MRI, PSA level and B-MRI combined, and PSAD and B-MRI combined for the detection of prostate cancer were assessed (Table 2). Examining the three individual measures for prostate cancer detection (PSA level, PSAD, and the number of SPL alone), the B-MRI number of SPL was noted to have the highest sensitivity (89%), whereas PSAD had the highest specificity (86%). The B-MRI number of SPL had a low specificity (54%). Of these three modalities, B-MRI number of SPL >1 had the highest NPV (78%) vs 56% and 52% for PSA level and PSAD, respectively. Combining modalities significantly improved the performance of these tests. The combined use of B-MRI with PSA level led to a high sensitivity (90%) with moderate specificity (63%). Conversely, combined use of B-MRI with PSAD led to high specificity (86%) with moderate sensitivity (74%). The NPV accordingly improved to 70% for PSAD with B-MRI and 82% for PSA with B-MRI. As intermediate findings on B-MRI such as 1 or >2 SPL may also be of interest, statistical performance of MRI for prostate cancer detection were calculated at these thresholds and is also represented (Table 3).

We simulated based on our study cohort, the results of using each of these five prostate cancer detection tests (PSA level, PSAD, B-MRI, PSA level+B-MRI, and PSAD+B-MRI). The cohort was divided into a 'test-negative' and 'test-positive' groups generated by application of each model with the appropriate thresholds (PSA level <4 vs ≥ 4 ng/mL, etc.). Figure 3A shows the distribution of biopsy Gleason score in the 'test-negative' population as determined by the five different models. Of interest, addition of MRI to the models improved detection of higher grade disease: PSA level and MRI combined missed no prostate cancer with biopsy Gleason score >7 . Use of PSAD and MRI combined resulted in the greatest number of men with no prostate cancer correctly categorised as screen negative while also minimising the number of biopsy Gleason score ≥ 7 cancers that were missed. Figure 3B shows the distribution of biopsy Gleason Score in those considered 'test positive'

for each modality and combination tested. Combined use of B-MRI with both PSA level and PSAD resulted in minimising the number of men with no cancer that were considered 'test positive', while capturing the most men harbouring biopsy Gleason score ≥ 7 disease. Overall, combined use of PSA level or PSAD coupled with B-MRI number of SPL improved the true-positive yield of identifying men with biopsy Gleason score ≥ 7 , while minimising the false-positive number of men identified as 'test positive' but with no cancer.

The overall utility of these modalities was examined using decision curve analysis in which the net benefit was calculated for all possible screening thresholds by weighing the benefit of identifying a true-positive against the weighted negative impact of a false-positive screening test (Fig. 4). Combined use of B-MRI with PSA level or PSAD had a greater net benefit vs any one modality alone. PSAD coupled with MRI showed the greatest net benefit of these modalities. Of additional interest, PSA level and PSAD were of no additional net benefit compared with an approach to biopsy all males unless the threshold probability for concern (expected incidence of prostate cancer in the population) was close to 40% for PSAD and 50% for PSA level (i.e. a very high-risk population). In contrast, all test models involving MRI showed benefit in even low-risk populations with threshold probabilities for concern of prostate cancer close to 10%.

Discussion

In the PSA era, widespread prostate cancer screening has resulted in a well-recognised downward stage migration toward organ-confined prostate cancer [2,13]. However, population-wide PSA screening has resulted in the over-diagnosis and overtreatment of clinically insignificant prostate cancer, largely due to its lack of specificity in detecting clinically significant prostate cancer [14,15]. This has, in part, prompted recommendations against PSA screening in all men by the USA Preventive Services Task Force [3,4]. In light of these recommendations and the continued public health concern posed by prostate cancer, significant efforts have been directed toward developing other screening approaches with the goal of minimising unnecessary biopsies by identifying patients with clinically significant cancers to minimise overtreatment.

MP-MRI has been developed and tested as an anatomical and functional evaluation of the prostate, which aids in overall prostate cancer detection and characterisation of higher-risk disease [16–18]. However, MP-MRI is considered relatively expensive and time consuming posing doubts about whether the healthcare system can accommodate its use as a screening study. If a more streamlined study could be designed, it might be possible to develop an effective imaging tool for identifying prostate cancer, analogous to the mammogram for breast cancer. Hence, we investigated the diagnostic utility of a B-MRI, incorporating only T2W and DWI sequences, which requires less than half the in-bore magnet time to perform compared with the complete MP-MRI at our institution, in conjunction with PSA testing.

We found that the number of lesions demonstrable on both B-MRI sequences, references as SPL, outperformed both PSA level and PSAD for the detection of prostate cancer in a population of patients with a clinical suspicion of prostate cancer. Furthermore, when the B-MRI number of SPL was combined with PSA level or PSAD, the sensitivity and specificity

further improved diagnostic accuracy for the detection of prostate cancer compared with PSA-based screening alone. Notably, the performance of PSA level and PSAD in this enriched patient population was heightened compared with some prior historical reports, probably due to the clinical suspicion of harbouring cancer in our patient population based on PSA parameters.

Based on the results of the present study, we showed PSA level or PSAD combined with B-MRI offer potential for improved detection of prostate cancer vs PSA measures alone. The benefit to using PSAD with B-MRI is that it performs similarly to PSA level alone in identifying patients with prostate cancer, but significantly decreases the number of men who are identified as 'test positive' yet have no cancer by 3.8-fold. The efficiency of the test to identify people with prostate cancer is thus increased with this approach from 67% of PSA 'test positive' men actually harbouring prostate cancer, to 89% of PSAD with B-MRI 'test-positive' men harbouring prostate cancer. The approach of PSA level with B-MRI, in contrast, does not show the same testing efficiency in identifying men with prostate cancer as PSAD with B-MRI, but is much more efficient at maximally identifying men with higher grade biopsy Gleason score ≥ 7 disease (PSA level identified 47/55, 85% vs PSA level with B-MRI which identified 52/55, 95%). Compared with PSA level alone, PSA level with B-MRI also had the added benefit of decreased overall number of false positives ('test-positive' men with no cancer) from 30 to 22 men.

Because it provides both anatomical and functional information, MRI has been touted as a method that can parse out more clinically significant prostate cancer foci that correlate well with tumour size, Gleason grade, and clinical stage [8,9,16,19]. Furthermore, the combination of B-MRI with PSA-based screening could optimise patient selection to decrease biopsies yielding benign findings or clinically insignificant disease, thereby focusing resources on men with more aggressive disease. The data also show that adding B-MRI as an adjunct filter to PSA-based screening allows for culling out more significant, biopsy Gleason score ≥ 7 disease in men.

One distinct challenge to the implementation of MRI into a screening paradigm is the time and cost of the study. To address this issue, we assessed B-MRI (i.e. just two of the parameters typically used during a full MP-MRI) in our study as a diagnostic tool for detection of prostate cancer. Furthermore, these parameters eliminated the need for a contrast-enhanced study, reducing the costs and time associated with placement of an i.v. access catheter for administration of MR contrast agents. Further reductions in cost could be achieved if scans were performed without endorectal coils. Many centres perform MP-MRI without an endorectal coil to decrease cost and limit in-bore magnet time. The present evaluation of B-MRI is a retrospective analysis of patients who underwent four-parameter MP-MRI with an endorectal coil in place. A recent study by Turkbey et al. [20] compared findings of dual-coil prostate MRI with both surface and endorectal coils in place immediately after MRI with a surface coil alone. The dual-coil study had a higher sensitivity and PPV when imaging findings were correlated to whole-mount radical prostatectomy findings. However, dominant tumours were identified in most cases, irrespective of the use of the endorectal coil. Perhaps, a future prospective investigation of B-MRI with and without

the endorectal coil could further elucidate the added value of the endorectal coil in prostate cancer detection given the higher costs and discomfort associated with its placement.

Other limitations of the present study are the limited sample size of patients who fit the inclusion criteria due to the referral pattern of our institution whereby most patients seeking MP-MRI and biopsy at our centre have previously undergone multiple prior biopsy sessions with no prostate cancer or minimal volume, low-grade disease diagnosed that was discordant with PSA levels or PSA dynamics observed. For our present analysis, we elected to only include patients who had not had prior prostate biopsies to eliminate the potential biases of including patients with biopsy findings discordant with biomarker assessment. Also, the cohort is not a true screening population but rather is a population that is enriched for pre-test degree of prostate cancer suspicion largely based elevated PSA levels. The reference test was limited to the biopsy findings on targeted biopsies found only on the B-MRI parameters in addition to the concurrent systematic 12-core biopsy, but this presents an incorporation bias inherent to our protocol whereby standard-of-care biopsy is coupled with targeted biopsy techniques. However, as future trials may implement MRI for screening, pilot studies such as this may provide baseline data and guidance about the integration of MRI into prostate cancer screening models. Future prospective, large-scale, long-term screening trials will ultimately be necessary to validate these findings and define the applicability of MRI in prostate cancer detection in populations of men who are not enriched by PSA-based clinical suspicion. Ideally, such a study will be a multi-institutional effort also evaluating the cost impact of these tools when incorporating number of biopsy sessions, treatment costs, and morbidities compared with the prior standard-of-care PSA-based screening alone.

In conclusion, the number of SPL on B-MRI, using only T2W and DWI, outperformed PSA level and PSAD in the detection of prostate cancer. When B-MRI was combined with PSA level and PSAD, even higher sensitivity and specificity was achieved and provided greater accuracy in detecting clinically significant disease. These data provide support for a limited non-contrast MRI as a potential adjunct tool to optimise prostate cancer detection.

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Abbreviations

AUC	area under the curve
DWI	diffusion-weighted imaging

(B)(MP)-MRI	(biparametric)(multiparametric-prostate)-MRI
PSAD	PSA density
(N)(P)PV	(negative)(positive) predictive value
ROC	Receiver operating characteristic
SPL	screen-positive lesions
T2W	T2-weighted
US	ultrasound/ultrasonography

References

1. Siegel R, Naishadham D, Jemal A. Cancer statistics, 2013. *CA Cancer J Clin.* 2013; 63:11–30. [PubMed: 23335087]
2. Derweesh IH, Kupelian PA, Zippe C, et al. Continuing trends in pathological stage migration in radical prostatectomy specimens. *Urol Oncol.* 2004; 22:300–6. [PubMed: 15283887]
3. US Preventive Services Task Force. Screening for Prostate Cancer: U.S. Preventive Services Task Force recommendation statement. Available at: <http://www.uspreventiveservicestaskforce.org/prostatecancerscreening/prostatefinalrs.htm>. Accessed February 2014
4. Moyer VA. U.S. Preventive Services Task Force. Screening for prostate cancer: U.S. Preventive Services Task Force recommendation statement. *Ann Intern Med.* 2012; 157:120–34. [PubMed: 22801674]
5. Andriole GL, Crawford ED, Grubb RL 3rd, et al. Mortality results from a randomized prostate-cancer screening trial. *N Engl J Med.* 2009; 360:1310–9. [PubMed: 19297565]
6. Schröder FH, Hugosson J, Roobol MJ, et al. Prostate-cancer mortality at 11 years of follow-up. *N Engl J Med.* 2012; 366:981–90. [PubMed: 22417251]
7. Rais-Bahrami S, Siddiqui MM, Turkbey B, et al. Utility of multiparametric magnetic resonance imaging suspicion levels for detecting prostate cancer. *J Urol.* 2013; 190:1721–7. [PubMed: 23727310]
8. Siddiqui MM, Rais-Bahrami S, Truong H, et al. Magnetic resonance imaging/ultrasound-fusion biopsy significantly upgrades prostate cancer versus systematic 12-core transrectal ultrasound biopsy. *Eur Urol.* 2013; 64:713–9. [PubMed: 23787357]
9. Bloch BN, Genega EM, Costa DN, et al. Prediction of prostate cancer extracapsular extension with high spatial resolution dynamic contrast-enhanced 3-T MRI. *Eur Radiol.* 2012; 22:2201–10. [PubMed: 22661019]
10. Pinto PA, Chung PH, Rastinehad AR, 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.* 2011; 186:1281–5. [PubMed: 21849184]
11. Turkbey B, Mani H, Aras O, et al. Prostate cancer: can multiparametric MR imaging help identify patients who are candidates for active surveillance? *Radiology.* 2013; 268:144–52. [PubMed: 23468576]
12. Vickers AJ, Elkin EB. Decision curve analysis: a novel method for evaluating prediction models. *Med Decis Making.* 2006; 26:565–74. [PubMed: 17099194]
13. Hernández J, Thompson IM. Prostate-specific antigen: a review of the validation of the most commonly used cancer biomarker. *Cancer.* 2004; 101:894–904. [PubMed: 15329895]
14. Etzioni R, Tsodikov A, Mariotto A, et al. Quantifying the role of PSA screening in the US prostate cancer mortality decline. *Cancer Causes Control.* 2008; 19:175–81. [PubMed: 18027095]
15. Wilt TJ, Brawer MK, Jones KM, et al. Radical prostatectomy versus observation for localized prostate cancer. *N Engl J Med.* 2012; 367:203–13. [PubMed: 22808955]

16. Rastinehad AR, Baccala AA Jr, Chung PH, et al. D'Amico risk stratification correlates with degree of suspicion of prostate cancer on multiparametric magnetic resonance imaging. *J Urol*. 2011; 185:815–20. [PubMed: 21239006]
17. Yerram NK, Volkin D, Turkbey B, et al. Low suspicion lesions on multiparametric magnetic resonance imaging predict for the absence of high-risk prostate cancer. *BJU Int*. 2012; 110:E783–8. [PubMed: 23130821]
18. Stamatakis L, Siddiqui MM, Nix JW, et al. Accuracy of multiparametric magnetic resonance imaging in confirming eligibility for active surveillance for men with prostate cancer. *Cancer*. 2013; 119:3359–66. [PubMed: 23821585]
19. Rais-Bahrami S, Turkbey B, Rastinehad AR, et al. Natural History of Small Index Lesions Identified on Multiparametric Prostate MRI Recommendations for interval imaging follow-up. *Diagn Interv Radiol*. 2014; doi: 10.5152/dir.2014.13319
20. Turkbey B, Merino MJ, Gallardo EC, et al. Comparison of endorectal coil and non-endorectal coil T2W and DW MRI at 3T for localizing prostate cancer: correlation with whole-mount histopathology. *J Magn Reson Imaging*. 2014; 39:1443–8. [PubMed: 24243824]

Fig. 1.
Predictive power of various individual detection measures.

Fig. 2.

(A) Predictive power of composite detection models combining the number of SPLs with PSA level or PSAD. (B) The optimal threshold for each composite detection model by determining the maximal point of sensitivity and specificity for each model.

Fig. 3. Distribution of biopsy Gleason scores on test negative (A) and positive (B) men.

Fig. 4.

Decision curve analysis comparing net benefits of different detection approaches. None = biopsy no one, All = biopsy everyone, MRI = the number of SPL, PSA level+MRI= PSA level + $6 \times$ (the number of SPL), PSAD+MRI= $14 \times$ (PSAD) + (the number of SPL).

Table 1

Demographics and MRI findings.

Characteristic	Total	No cancer	Cancer	<i>P</i>
Number of men	143	59	84	
Mean (SD):				
Age, years	60.7 (7.7)	59.2 (7.2)	61.8 (7.9)	<0.05
PSA level, ng/mL	6.8 (6.5)	4.6 (2.7)	8.3 (7.8)	<0.001
PSAD, ng/mL/mL	0.15 (0.14)	0.09 (0.05)	0.19 (0.16)	<0.001
Volume, mL	48.1 (25.2)	53.8 (30.8)	44.3 (19.7)	0.02
N (%):				
DRE staging:				0.03
cT1c	123 (86)	55 (93)	68 (81)	
cT2	20 (14)	4 (7)	16 (19)	
Race:				0.1
White	104 (72)	46 (78)	58 (69)	
Black	23 (16)	4 (7)	19 (23)	
Other	16 (11)	9 (15)	7 (8)	
Biopsy Gleason score:				
No cancer	59 (41)			
Gleason 6	29 (20)			
Gleason 7	24 (17)			
Gleason 8	31 (22)			

Table 2

Performance of PSA level, PSAD, the number of SPL, and composite detection models incorporating the number of SPL with PSA level and PSAD in detecting prostate cancer.

	PSA level (threshold > 4 ng/mL), n/N (%)	PSAD (threshold > 0.15 ng/mL/mL), n/N (%)	Number of SPL (threshold >1), n/N (%)	Composite (6 × the number of SPL + PSA >14), n/N (%)	Composite (the number of SPL + 14 × PSAD >4.25), n/N (%)
Sensitivity	60/84 (71)	36/84 (43)	75/84 (89)	76/84 (90)	62/84 (74)
Specificity	30/59 (51)	51/59 (86)	32/59 (54)	37/59 (63)	51/59 (86)
PPV	60/89 (67)	36/44 (82)	75/102 (74)	76/98 (78)	62/70 (89)
NPV	30/54 (56)	51/99 (52)	32/41 (78)	37/45 (82)	51/73 (70)
Overall accuracy	90/143 (63)	87/143 (61)	107/143 (75)	113/143 (79)	113/143 (79)

Table 3

Detection characteristics of various B-MRI SPL thresholds.

Number of SPL	Sensitivity, n/N (%)	Specificity, n/N (%)	PPV, n/N (%)	NPV, n/N (%)	Overall accuracy, n/N (%)
>0	84/84 (100)	7/59 (12)	84/136 (62)	7/7 (100)	91/143 (64)
>1	75/84 (89)	32/59 (54)	75/102 (74)	32/41 (78)	107/143 (75)
>2	56/84 (67)	45/59 (76)	56/70 (80)	45/73 (62)	101/143 (71)
>3	27/84 (32)	57/59 (97)	27/29 (93)	57/114 (50)	84/143 (59)
>4	12/84 (14)	58/59 (98)	12/13 (92)	58/130 (45)	70/143 (49)