Usefulness of Grayscale Values of Hypoechoic Lesions Matched with Target Lesions Observed on Magnetic Resonance Imaging for the Prediction of Clinically Significant Prostate Cancer

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Abstract

INTRODUCTION:

To analyze grayscale values for hypoechoic lesions matched with target lesions evaluated using prebiopsy magnetic resonance imaging (MRI).

METHODS

We collected data on 420 target lesions in patients who underwent MRI/transrectal ultrasound fusion biopsies. Images of hypoechoic lesions that matched the target lesions on MRI were stored in a picture archiving and communication system, and their grayscale values were estimated using the red/green/blue scoring method through an embedded function. We analyzed imaging data using grayscale values.

RESULTS

Of the 420 lesions, 261 (62.1%) were prostate cancer lesions. Grayscale ranges (42.6–91.8) were significant predictors of clinically significant prostate cancer (csPC) in multivariable logistic regression analyses. Area under the curve for detecting csPC using grayscale values along with conventional variables was 0.839, which was significantly higher than that for detecting csPC using only conventional variables (0.828; $p = 0.036$). Subgroup analysis revealed a significant difference for PI-RADS 3 lesions between grayscale values for benign and cancerous lesions ($p = 0.008$). Grayscale values were the only significant predictive factor ($p = 0.005$) for csPC.

CONCLUSIONS

Distribution of grayscale values according to PI-RAD 3 scores was useful, and the grayscale range (42.6–91.8) was an important factor for csPC diagnosis.

Introduction

Prebiopsy magnetic resonance imaging (MRI) is recommended as a primary screening tool for patients suspected of having prostate cancer (PCa)¹. Results of prostate MRI are classified based on the presence or absence of visible lesions. For patients with visible lesions, the likelihood of PCa diagnosis increases with the detection of lesions². Introduction of the Prostate Imaging-Reporting and Data System (PI-RADS) for the diagnosis of clinically significant PCa (csPC) standardized the interpretation of MRI results for visible lesions³. The rate of PCa diagnosis increases with increasing PI-RADS scores (PI-RADS 3: 29.7%, PI-RADS 4: 42.3%, PI-RADS 5: 82.4%)⁴. For improving cost-effectiveness, new strategies for improving the

diagnostic accuracy of PI-RADS have been investigated^{5–7}. For improving the specificity of screening, the National Comprehensive Cancer Network Clinical Practice Guidelines in Oncology for PCa Early Detection recommend using tests and scores associated with biomarkers levels, such as the Prostate Health Index, SelectMDx® test, 4Kscore® test, and ExoDx™ Prostate Test, as additional useful tools¹; however, biomarkers were not considered the diagnostic tool for evaluating target lesions on MRI.

van de Ven et al. reported that the presence of a clearly hypoechoic lesion in MRI/transrectal ultrasound (TRUS) fusion-targeted biopsy was associated with the prediction of high-grade PCa⁸. Therefore, we hypothesized that analysis of target lesions on TRUS matched with those observed on MRI during MRI/TRUS fusion-targeted biopsies might be useful for stratifying the lesions according to the PI-RADS scores. In addition, we conducted an experimental study to evaluate whether, with respect to systematic biopsies, high-grade PCa lesions can be subdivided if grayscale values for hypoechoic lesions are considered in addition to conventional variables such as age, prostate-specific antigen (PSA) levels, and prostate volume (PV)⁹. This study aimed to confirm the effectiveness of analyzing hypoechoic lesions using grayscale values. Additionally, we suggested a range of grayscale values for improving the prediction of PCa in addition to the PI-RADS.

Results

Baseline characteristics of the patients and grayscale

Baseline characteristics of the patients and target lesions are shown in Table 1. Age, PSA level, PV, and the PI-RADS score were significantly different between the benign and PCa groups. The CDR was 36.1% (43/119) in patients with PI-RADS 3 lesions, 62.7% (126/201) in patients with PI-RADS 4 lesions, and 92.0% (92/100) in patients with PI-RADS 5 lesions (Table 1). There were no significant differences between the grayscale values for benign and cancerous lesions (70.3 vs. 65.9, $p = 0.359$). The grayscale range for predicting PCa was 41.8–98.5 and that for predicting csPC was 42.6–91.8.

Table 1
Baseline characteristics of target lesions

	Prostate cancer		<i>P value</i>
	No (n = 159)	Yes (n = 261)	
Age (years)	66.7 ± 8.5	70.4 ± 7.8	< 0.001
PSA (ng/mL)	5.83 (4.60–8.09)	7.97 (5.37–14.22)	0.001
Prostate volume (cm ³)	41.2 ± 15.2	34.0 ± 15.1	< 0.001
PSAD (ng/mL/cm ³)	0.15 (0.11–0.23)	0.27 (0.17–0.47)	0.002
Previous prostate biopsy history	43 (27.0)	41 (15.7)	0.007
Positive systemic biopsy	35 (22.0)	233 (89.3)	< 0.001
Gleason score			< 0.001
6	17 (48.6)	59 (25.3)	
≥ 7 (3 + 4)	18 (51.4)	174 (74.7)	
No. of positive systemic biopsy cores	0.6 ± 1.4	4.6 ± 3.4	< 0.001
Target lesions			0.642
Peripheral zone	37 (23.3)	66 (25.3)	
Transitional zone	122 (76.7)	195 (74.7)	
Target lesion size	1.01 ± 0.80	1.59 ± 1.09	< 0.001
PI-RADS			< 0.001
3	76 (63.9)	43 (36.1)	
4	75 (37.3)	126 (62.7)	
5	8 (8.0)	92 (92.0)	
Grayscale	70.3 (45.3–98.4)	65.9 (47.7–89.9)	0.359
Data are expressed as number (%) and median (interquartile range).			
PI-RADS, prostate imaging-reporting and data system; PSA, prostate-specific antigen; PSAD, prostate-specific antigen density			

Grayscale values as a predictor of PCa and csPC

Univariable analysis for PCa and csPC identified age, PSA level, PV, previous prostate biopsy history, the PI-RADS score, and grayscale values as potential predictors of PCa and csPC (Table 2). Multivariable

analysis to evaluate the predictive ability of grayscale values in addition to conventional variables revealed that grayscale values were a significant predictor of PCa and csPC (Table 3).

Table 2
Logistic regression analyses for predicting the presence of prostate cancer

	Univariable analysis		Multivariable analysis	
	OR (95% CI)	<i>p</i> <i>value</i>	OR (95% CI)	<i>p</i> <i>value</i>
Age (years)	1.06 (1.032–1.085)	< <i>0.001</i>	1.05 (1.020–1.086)	<i>0.001</i>
PSA (ng/mL)	1.06 (1.028–1.101)	< <i>0.001</i>	1.05 (1.006–1.092)	<i>0.025</i>
Prostate volume (cm ³)	0.97 (0.957–0.983)	< <i>0.001</i>	0.96 (0.942–0.975)	< <i>0.001</i>
Previous prostate biopsy history	0.50 (0.310–0.815)	<i>0.049</i>	0.57 (0.322–0.999)	<i>0.050</i>
PI-RADS		< <i>0.001</i>		< <i>0.001</i>
4 vs. 3	2.97 (1.854–4.754)	< <i>0.001</i>	2.62 (1.544–4.449)	< <i>0.001</i>
5 vs. 3	20.33 (9.010–45.851)	< <i>0.001</i>	12.70 (5.268–30.597)	< <i>0.001</i>
Grayscale (41.8–98.5)	1.63 (1.088–2.432)	<i>0.018</i>	1.77 (1.087–2.868)	<i>0.022</i>
CI, confidence interval; OR, odds ratio; PI-RADS, prostate imaging-reporting and data system; PSA, prostate-specific antigen; PSAD, prostate-specific antigen density				

Table 3
Logistic regression analyses for predicting the presence of significant prostate cancer

	Univariable analysis		Multivariable analysis	
	OR (95% CI)	<i>p</i> <i>value</i>	OR (95% CI)	<i>p</i> <i>value</i>
Age (years)	1.06 (1.032–1.085)	< <i>0.001</i>	1.05 (1.018–1.085)	<i>0.002</i>
PSA (ng/mL)	1.05 (1.027–1.082)	< <i>0.001</i>	1.04 (1.007–1.064)	<i>0.014</i>
Prostate volume (cm ³)	0.97 (0.959–0.986)	< <i>0.001</i>	0.96 (0.938–0.973)	< <i>0.001</i>
Previous prostate biopsy history	0.55 (0.332–0.899)	<i>0.017</i>	0.71 (0.390–1.294)	<i>0.264</i>
PI-RADS		< <i>0.001</i>		< <i>0.001</i>
4 vs. 3	4.01 (2.304–6.992)	< <i>0.001</i>	3.88 (2.104–7.163)	< <i>0.001</i>
5 vs. 3	25.99 (12.664–53.326)	< <i>0.001</i>	20.375 (9.211–45.069)	< <i>0.001</i>
Grayscale (42.6–91.8)	1.72 (1.162–2.537)	<i>0.007</i>	2.11 (1.298–3.443)	<i>0.003</i>
CI, confidence interval; OR, odds ratio; PI-RADS, prostate imaging-reporting and data system; PSA, prostate-specific antigen; PSAD, prostate-specific antigen density				

The AUC for detecting csPC using grayscale values in addition to conventional variables was 0.839, which was significantly higher than that for detecting csPC using only conventional variables (0.828; $p = 0.036$) (Fig. 1). Sensitivity and specificity of grayscale values were 62.4% and 50.9%, respectively. However, with respect to predicting PCa, no differences were found between prediction using only conventional variables and that using grayscale values in addition to conventional variables (0.828 vs. 0.817, $p = 0.145$).

Usefulness of grayscale values for predicting csPC in patients with PI-RADS 3 lesions

We analyzed the prediction of PCa and csPC using the grayscale values for all PI-RADS scores (Table 4). For groups of individuals with cancer of the same PI-RADS score, the proportion of individuals with high-grade cancer increases with increasing PI-RADS scores ($p < 0.001$). For cancer lesions, grayscale values showed the tendency of increasing and paradoxically decreasing with increasing PI-RADS scores (Gleason grade group 1: 58.8 [44.8–94.3], Gleason grade group 2–3: 73.2 [50.0–93.7], Gleason grade group 4–5: 65.6 [47.7–92.2]). With respect to PI-RADS 3 lesions, the grayscale values were significantly different between cancerous and benign lesions (58.8 [44.8–94.3] and 74.5 [54.8–99.2], respectively; $p =$

0.008), whereas for lesions with PI-RADS score of 4 or 5, there was no significant difference between the grayscale values.

Table 4
Grayscale value according to target lesion of PI-RADS

	PI-RADS 3	PI-RADS 4	PI-RADS 5	<i>p value</i>
Gleason grade group				<i>< 0.0001</i>
1	23 (53.5)	36 (28.6)	8 (8.7)	
2–3	12 (27.9)	64 (50.8)	41 (44.6)	
4–5	8 (18.6)	26 (20.6)	43 (46.7)	
Grayscale				
Total	65.6 (47.0–94.7)	69.7 (45.5–93.7)	65.7 (47.7–91.7)	<i>0.915</i>
Benign	74.5 (54.8–99.2)	61.5 (39.5–93.7)	82.9 (34.5–91.5)	<i>0.304</i>
Cancer	58.8 (44.8–94.3)	73.2 (50.0–93.7)	65.6 (47.7–92.2)	<i>0.077</i>
<i>p value</i>	<i>0.008</i>	<i>0.398</i>	<i>0.838</i>	
Data are expressed as number (%) and median (interquartile range).				
PI-RADS, prostate imaging-reporting and data system				

For PI-RADS 3 lesions, the grayscale range for predicting PCa was 36.2–89.7 and that for predicting csPC was 42.9–71.9. Multivariable analysis in which variables such as age, PV, and grayscale values were considered identified age (odds ratio [OR] = 1.08; confidence interval [CI]: 1.026–1.134; *p* = 0.003) and PV (OR = 0.95; CI: 0.911–0.980; *p* = 0.002) as predictors of PCa diagnosis (Table 5). Grayscale values were not found to be a significant predictor. The AUC for detecting PCa using grayscale values in addition to conventional variables was 0.702, which was significantly higher than that for detecting PCa using only conventional variables (0.656; *p* = 0.001). For csPC, grayscale values were identified as the only independent significant predictor (OR = 4.46; CI: 1.573–12.652; *p* = 0.005) (Table 5). For PI-RADS 3 lesions, the sensitivity and specificity of the grayscale range (42.9–71.9) for detecting csPC were 0.487 and 0.767, respectively.

Table 5

Logistic regression analyses for predicting the presence of prostate cancer and clinically significant prostate cancer in PI-RADS 3 lesion

Cancer	Univariable analysis		Multivariable analysis	
	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value
Age (years)	1.07 (1.017–1.116)	<i>0.007</i>	1.08 (1.026–1.134)	<i>0.003</i>
PSA (ng/ml)	1.02 (0.980–1.060)	<i>0.346</i>		
Prostate volume (cm ³)	0.95 (0.919–0.983)	<i>0.003</i>	0.95 (0.911–0.980)	<i>0.002</i>
Previous prostate biopsy history	0.91 (0.378–2.186)	<i>0.831</i>		
Grayscale (36.2–89.7)	3.13 (1.354–7.240)	<i>0.008</i>	2.26 (0.905–5.624)	<i>0.081</i>
Significant prostate cancer	Univariable analysis		Multivariable analysis	
	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value
Age (years)	1.04 (0.985–1.106)	<i>0.146</i>		
PSA (ng/ml)	1.01 (0.966–1.053)	<i>0.691</i>		
Prostate volume (cm ³)	0.96 (0.919–1.0020)	<i>0.062</i>		
Previous prostate biopsy history	0.74 (0.226–2.422)	<i>0.619</i>		
Grayscale (42.9–71.9)	4.46 (1.573–12.652)	<i>0.005</i>		
CI, confidence interval; OR, odds ratio; PI-RADS, prostate imaging-reporting and data system; PSA, prostate-specific antigen				

Discussion

The presence of visible lesions on prebiopsy MRI increases the likelihood of PCa diagnosis. For classifying visible lesions identified on prebiopsy MRI, the PI-RADS was developed for predicting csPC and interpreting MRI results^{3,10}. In order to increase the efficacy of using prebiopsy MRI results for the prediction of PCa and csPS^{11–14}, new methods for the classification of lesions are needed. We hypothesized that image analysis of hypoechoic lesions on TRUS matched with target lesions on MRI in MRI/TRUS fusion-targeted biopsies could be used effectively for predicting PCa and csPC. Using grayscale values in addition to conventional variables was helpful for increasing the probability of correctly detecting csPC. Especially, with respect to PI-RADS 3 lesions, grayscale values were identified as the only discriminating factor for benign and cancerous lesions.

Until now, several studies have reported that the presence of hypoechoic lesions with definite visibility in TRUS is related to the diagnosis of csPC with or without visible lesions on MRI^{2,15}. However, in several guidelines, hypoechoic lesions have not been included as indicators for prostate biopsy^{1,16,17}. The

reasons were considered as lack of reproducibility and representativeness associated with subjective measurements of hypoechoicity for selecting hypoechoic lesions and the fact that increasing cancer aggressiveness has an effect on fibrotic change and echogenicity, which show apparent differences on ultrasound images of PCa¹⁸. To overcome limitations regarding reproducibility and representativeness, in our previous study, we reported the usefulness of grayscale values for the quantitation and stratification of hypoechoic lesions on cancer aggressiveness⁹. In the present study, through quantification with grayscale values, we showed that the characteristics of visible lesions observed through TRUS reaffirmed the results of a previous study².

To the best of our knowledge, no studies involving the use of numerical analyses, such as the analysis of grayscale values for explaining the relationship between increasing cancer aggressiveness and hypoechoicity, have been conducted. Therefore, we collected and analyzed the images obtained during MRI/TRUS fusion-targeted biopsies. Regarding the measurement of grayscale values for target lesions, no difference was found between the median grayscale values for benign and cancerous lesions. However, the grayscale value interquartile range for benign lesions was larger than that for cancerous lesions. Therefore, we identified the optimal grayscale range for predicting PCa and csPC. Finally, we confirmed that the grayscale range was a significant predictive factor of PCa and csPC. Combined evaluation of clinical variables and images increases the accuracy of predicting csPC, which is consistent with the results of our previous study⁹.

For PI-RADS 3 lesions, there was a relatively low predicting ability for PCa diagnosis^{19–21}. Therefore, several researchers investigated the discrimination of PI-RADS 3 lesions using clinical parameters and biomarkers^{22,23}. Sheridan et al. reported that when PI-RADS 3 lesions are present, csPC detection rates can be increased by evaluating factors such as clinical parameters (age $\geq$ 70 years, size $\leq$ 36 cm³, positive digital rectal examination)⁷. Another study found that evaluation of the Prostate Health Index in addition to MRI results improved the predictive performance for overall cancer (AUC 0.71 vs. 0.60) and csPC detection (AUC 0.75 vs. 0.64)⁵. Our findings may improve the rate of accurate overall cancer diagnosis (AUC 0.70 vs. 0.66) among individuals with PI-RADS 3 lesions. For predicting csPC in PI-RAD 3, the grayscale characteristics of target lesions was the only factor in this study.

Certain meaningful findings were made in this study. First, we presented the grayscale range for predicting csPC through a quantitative image analysis of target lesions matched in MRI/TRUS fusion-targeted biopsies. This use of grayscale values is a novel method to stratify suspicious cancer lesions on MRI. Second, previous studies on PCa diagnosis in hypoechoic lesions estimated with low accuracy due to several reasons. Through this study, we present objective findings that explain correlations between echogenicity and histologic grade, which were not made in previous studies¹⁸. Furthermore, we qualitatively confirmed this change pattern for the first time through the grayscale trend according to the Gleason grade group. Measurement of the grayscale values requires minimal expenditure because they are measured using ultrasound, which is used for TRUS, and PACS can be used to store TRUS results, instead of a new equipment. A limitation of our study is that it is a single-institution study. For external

validation, a multicenter study must be performed in future. Moreover, it is necessary to study whether different results would be obtained if ultrasonic equipment produced by different companies is used.

The efficacy of prebiopsy MRI has been proven; however, with respect to detecting PCa, results associated with PI-RADS 3 lesions have been equivocal. We confirmed the distribution of grayscale values according to the PI-RADS scores and found that the grayscale values of hypoechoic lesions on TRUS are an important predictor of csPC. Our results showed that for PI-RADS 3 lesions, grayscale values were useful to predict csPC, and the cut-off range was 42.9–71.9.

Methods

Ethic approval

This study was approved by the institutional ethics committee (Yonsei university health system, Seoul, Korea, 3-2020-0236), and all procedures were conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments. The informed consent requirement was waived by ethics committee of Yonsei university health system because this study was based on retrospective, anonymous patient data and did not involve patient intervention or the use of human tissue samples.

Patient selection

We collected data on 449 consecutive patients who underwent MRI/TRUS fusion-targeted biopsies at our institution between January 2017 and September 2020. Indications for prebiopsy MRI with national reimbursement policy were elevated PSA level, identification of palpable nodules during digital rectal examinations, presence of hypoechoic lesions suspected of being PCa lesions, and/or PSA levels > 100 ng/mL. We recommended prostate biopsy for patients with PSA levels > 3.0 ng/mL, palpable nodules identified through digital rectal examinations, continuous elevations in PSA levels during follow-up periods, and/or relevant prebiopsy MRI findings.

Of 580 target lesions in the 449 patients (median age: 69.3 years [interquartile range: 62.9–75.3]; median PSA level: 7.02 ng/mL [5.00–11.00]; median PV: 32.8 cm³ [25.7–45.9], median PSA density (PSA level divided by PV): 0.20 ng/mL/cm³ [0.13–0.36]; number of patients diagnosed with PCa: 312 [69.5%]; number of patients with previous prostate biopsy history: 100 [22.3%]; cancer detection rate [CDR] in patients with PI-RADS 3 lesions: 57/180 [31.7%]; CDR in patients with PI-RADS 4 lesions: 156/255 [61.2%]; CDR in patients with PI-RADS 5 lesions: 136/150, [90.7%]), 160 were excluded from the study for the following reasons: (i) for 120 patients, no TRUS images were obtained during MRI/TRUS fusion-targeted biopsies; (ii) for 16 patients, the quality of ultrasound images was poor; and (iii) three patients were diagnosed as having neuroendocrine tumors. Finally, 420 target lesions were included in this study.

Data collection

Data on patient characteristics, including clinicopathological data such as age, history of prostate biopsy, PV, PSA level, PSA density, MRI findings, and TRUS images, were obtained.

MRI protocol and imaging analysis

Imaging was performed using a 3-T MRI system (Intera Achieva 3.0 T, Phillips Medical System, Best, the Netherlands), equipped with a six-channel phased-array coil. The prostate MRI protocol involved diffusion-weighted imaging in addition to T2-weighted imaging. Images were acquired through T2-weighted turbo spin-echo MRI in three planes (axial, sagittal, and coronal). MRI datasets were obtained at identical slice locations, with a slice thickness of 3 mm and no intersection gap. Two b-values (0–1400 s/mm²) were used, and diffusion restriction was quantified via apparent diffusion coefficient mapping. Dynamic contrast-enhanced MRI was also performed.

Uro-radiologists denoted suspicious regions of interest on the apparent diffusion coefficient maps examined using the Digital Imaging and Communications in Medicine workstation. The PI-RADS scoring system was used to describe MRI findings³. Visible lesions were defined as lesions with PI-RADS scores ≥ 3 .

MRI-targeted biopsy technique

Prostate biopsies were performed after periprostatic nerve blocks had been administered using Chiba needles. Initially, four MRI-targeted cores biopsies for each targeted lesion were performed, followed by 12-core biopsies. MRI/TRUS fusion targeted biopsies were performed with an MRI/TRUS-fusion-targeted-biopsy protocol using the bk3000 ultrasound system, which involves the use of a side-fire ultrasound probe (BK Medical, Peabody, MA, USA) and an image-based fusion system (BioJet; GeoScan, Lakewood Ranch, FL, USA). All prostate biopsies were performed by an experienced urologist using an 18-gauge, 20-cm disposable core biopsy instrument (Max-Core™; BD, BD Headquarters, NJ, USA).

Ultrasound image analysis

Ultrasound images of target lesions observed on MRI were stored concomitantly using a picture archiving and communication system (PACS) (GE Healthcare, Barrington, IL, USA). We analyzed the grayscale version of the images using a red/green/blue (RGB) scoring method through a function embedded in the PACS. An average RGB value was obtained from scores at three other randomized points in the most identical slice. Grayscale values were replaced with RGB values on a pixel-by-pixel basis ($Y = 0.2126 \cdot R + 0.7152 \cdot G + 0.0722 \cdot B$)²⁴. Two investigators measured the average of three points, and we confirmed there were no differences in grayscale through paired sample t-tests.

Study objectives

Our primary objective was to investigate the efficacy of imaging analysis by quantifying hypoechoic lesions in MRI-target lesions, demonstrating its diagnostic accuracy, and specifying the quantitation range of hypoechoic lesions for the prediction of PCa and csPC. Our secondary objective was to identify the grayscale range for improving the prediction of PCa and csPC in addition to PI-RADS.

Statistical analysis

Continuous variables are expressed as medians (interquartile range) or mean $\pm$ standard deviation, and categorical variables as number of occurrences and frequency. Pearson's χ^2 test was used for statistical comparisons of continuous and categorical variables. Univariable and multivariable logistic regressions were used. Receiver operating characteristic (ROC) curves and areas under the ROC curves (AUCs) were used to evaluate the performance of standard clinical parameters (including age, previous prostate biopsy history, PSA level, PV, and PI-RADS score) versus the grayscale values in addition to standard clinical parameters for the diagnosis for PCa and csPC (defined as PCa of Gleason grade group ≥ 2) for target lesions. Pairwise comparisons of ROC curves were conducted to compare the predictive performance of individual and combined parameters. The cut-off value was assessed from the AUCs. These optimal cut-off values were based on predefined values and an analysis performed using the Youden index (sensitivity + specificity – 1). All statistical comparisons were conducted with IBM® SPSS® Statistics 25 (IBM, Armonk, NY, USA) and MedCalc version 11.6 (MedCalc Software Ltd, Acaciaaan, Ostend, Belgium). For differences, $p < 0.05$ was considered statistically significant.

Declarations

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Competing of interests

All authors declare that they have no conflicts of interest.

Data availability

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethical approval

This study was approved by the institutional ethics committee (Yonsei university health system, Seoul, Korea, 3-2020-0236), and all procedures were conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments. The informed consent requirement was waived by ethics committee of Yonsei university health system because this study was based on retrospective, anonymous patient data and did not involve patient intervention or the use of human tissue samples.

Consent to participate/Consent to publish: Not applicable

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AUTHOR CONTRIBUTIONS

Protocol/project development: DGK, KSL

Data collection and management: DGK, JWY, KCK, BHC, KSL

Data analysis: JWY, KSL

Manuscript writing/editing: DGK, JWY, KSL

All authors read and approved the final manuscript.

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Figures

Figure 1

The ROC curves for detecting csPC using conventional variables versus grayscale values in addition to conventional variables ROC, receiver operating characteristic; csPC, clinically significant prostate cancer