BMC Urology

RESEARCH

Open Access

How lesions proportional density shapes MRI cognitive fusion biopsy outcomes; finding the needle in the haystack

Volkan Sen[1], Ege A. Sarikaya[1,2*], Can Sinirsiz[1], Can Ahmet Karabacak[1], Muhammed Selcuk Ozer[1], Canan Altay[3], Burcin Tuna[4], Kutsal Yorukoglu[4], Ozan Bozkurt[1] and Ilhan Celebi[1]

Abstract

Objective To evaluate the importance of lesion density (lesion volume/prostate volume) on prostate cancer (PCa) and clinically significant prostate cancer (csPCa) detection rates in cognitive targeted biopsy (cTB).

Materials and methods 300 consecutive patients who underwent combined transrectal cTB and systematic transrectal prostate biopsy were included retrospectively. Lesion density was calculated as the largest lesion volume divided by prostate volume. According to ROC analysis and Youden's index, patients were grouped into low lesion density (Low-LD) and high lesion density (High-LD) groups. Detection rates of PCa and csPCa were compared. Subgroup analyses were performed for high PI-RADS lesions (4–5) and anatomical zones.

Results Mean lesion diameter and prostate volume were 14.1 ± 7.2 mm and 83.9 ± 42.8 mm^3, respectively. High lesion density was independently associated with csPCa in univariate and multivariate analysis ($p < 0.05$). PCa and csPCa detection rates were significantly higher in the High-LD group (53.6% vs. 32.0%, $p < 0.001$; and 37.1% vs. 16.7%, $p < 0.001$, respectively). Similar results were observed when only MRI-targeted cores were analysed. Subgroup analysis of PI-RADS 4–5 lesions confirmed that csPCa detection rates were also higher in High-LD group (39.0% vs. 21.5%, $p = 0.005$). csPCa detection was lowest in anterior lesions, especially in Low-LD patients (6%).

Conclusions Lesion density significantly affects the diagnostic accuracy of cTB. Patients with low lesion density have lower csPCa detection rates and may benefit from software-assisted fusion targeting over cognitive targeting.

Keywords Prostate cancer, Cognitive targeted biopsy, Lesion density, PI-RADS, Multiparametric MRI

*Correspondence:
Ege A. Sarikaya
ege.sarikaya@deu.edu.tr
[1]Faculty of Medicine, Department of Urology Turkey, Dokuz Eylül University, İzmir, Turkey
[2]Department of Urology Turkey, Uşak University Training and Research Hospital, Uşak, Turkey
[3]Faculty of Medicine, Department of Radiology Turkey, Dokuz Eylül University, İzmir, Turkey
[4]Faculty of Medicine, Department of Pathology Turkey, Dokuz Eylül University, İzmir, Turkey

© The Author(s) 2026. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

Introduction

Prostate cancer (PCa) has the second highest incidence with 29.4/100.000 among all cancers in men [1]. Needle biopsy by transrectal or transperineal approach is the standard procedure in case of suspicion. More than a decade ago, suspicion of PCa was only based on positive digital rectal examination finding and elevated PSA levels. With improvements in MRI and utilization of Prostate Imaging Reporting and Data System (PI-RADS v2.1), multiparametric prostate MRI (mpMRI) has begun to play a crucial role in both decision making in biopsy indication and targeting suspicious lesions.

European urology guidelines currently suggest performing mpMRI (if possible) for all patients with a PSA level between 3 and 20 ng/mL and performing an MRI-targeted biopsy if indicated [2]. There are three main different techniques for targeting defined lesions; in-bore MRI, software-assisted fusion targeted biopsy (saTB) and cognitive fusion targeted biopsy (cTB), with latter two being more widely used. In-bore MRI targeting has the highest cost and technical requirements, limiting its widespread availability. In saTB, a specialized software registrates the images of MRI into real-time ultrasonographic imaging during procedure, thus aiding clinician to obtain more accurate biopsies of targeted lesion. In cTB, clinician previews the mpMRI, recognizes the characteristic and location of lesion and targets the lesion in ultrasonographic guidance using anatomic landmarks and lesion characteristics [3, 4].

Most of the studies including meta-analysis and reviews indicated that saTB and cTB has similar rates of detecting PCa and clinically significant PCa (csPCA) [4–9] while a few studies showed higher detection rates for saTB [3, 10, 11]. Along with general opinion and guideline recommendations that saTB and cTB has similar detection rates for csPCA, it must be noted that factors that would impair accuracy of targeting such as, smaller lesion density (lesion volume / prostate volume) and anterior localisation (in transrectal approach) can seriously affect the cognitive targeting, while software-assisted targeting should better overcome these factors with real-time imaging. Some studies reported higher detection rates for saTB in smaller lesions [3, 12]. However, no study so far has investigated the relation between lesion density and PCa/csPCA detection rate. In this study, we aimed to show the decrease in both PCa and csPCa detection rates with lower lesion density in transrectal cTB biopsies.

Methods

Consecutive patients who underwent combined transrectal cTB and systematic transrectal ultrasonographic prostate needle biopsy in our institution between November 2021 and April 2024 were retrospectively included. Patients with a higher PSA value than 20 ng/mL were not included and total of 300 patients were included. Indications for biopsy were determined by clinicians according to DRE findings, PSA values and PIRADS scores. All mpMRI's were evaluated by a specialized radiologist. Positive DRE finding (nodularity, irregularity and stiffness suggestive of malignancy) and PSA levels greater than 10 mg/dL were indications for biopsy. For patients with PSA levels between 3 and 10 ng/mL, having high PSA density (>0.2) and presence of a PIRADS 4 or 5 lesion were indications for biopsy. Systematic biopsy was consisted of 12 peripheral cores and cTB were consisted of 3–5 cores per defined lesion. Gleason score 3 + 3 or higher were assumed as PCa and 3 + 4 or higher were assumed as csPCa.

Multiparametric MR images were obtained using a 1.5 T system (Philips Ingenia, Best, The Netherlands). An eight-channel phased-array body coil was used for signal reception from the patients' prostate. The sequences used in this study were as follows: sagittal TSE T2-weighted, axial TSE T2-weighted, axial TSE T1-weighted, oblique coronal TSE T2-weighted, axial TSE T2-weighted fat-saturated sequence encompassing pelvic lymph nodes to the level of the aortic bifurcation, and axial diffusion weighed echo-planar imaging (DW EPI) sequence combined with spectral fat saturation with 24 values of 0, 1000, and 1500 s/mm2. After the intravenous administration of 0.2 mL/kg of gadolinium chelate compound, dynamic pre- and postcontrast-enhanced images were acquired axial plane with 3D fat-suppressed GE T1-weighted volumetric interpolated breath-hold sequence (mDIXON) sequence.

Lesion density was calculated as largest lesion volume / prostate volume Ellipsoid formula was used for calculating lesion volume and bullet formula was used for calculating prostate volume. The patients were divided into two groups according to ROC analysis, low lesion density (Low-LD) and high lesion density (High-LD). Chi-square test was used for categorical variables and Man-Whitney U test was used for quantitative variables according to variables disturbance. Z-test was used to compare diagnostic value and accuracy of cTB between two groups.

A subgroup analysis for high PIRADS lesions (4 or 5) and anatomic zones were also performed between two groups. Chi-square was performed in high PIRADS and zonal subgroup analysis. SPSS version 29.0 was used for statistical analysis.

Results

Mean largest lesion diameter was 14,09 mm (±7.15) and mean prostate volume was 83.9 mm^3 (±42.8) (Table 1). Clinical parameters used in decision making for biopsy are given in Table 2. Total of 59 patients had a previous negative biopsy (most of them only systematic), 18 in high-LD group and 41 in low-LD group. Groups were

Table 1 Clinical characteristics and demographics of patients in two groups

	Low-ND (203)	High-ND (97)	*P***
Age, median (min-max)	64.2 (46–80)	65.6 (50–84)	0.048
Smoking* (+), %	36.5 (73)	31.6 (30)	0.407
Positive DRE. %	24.1 (49)	32 (31)	0.152
PIRADS Score.%			
3 or lower	29.1 (59)	15.5 (15)	
4–5	70.9 (144)	84.5 (82)	***0.011***
PSA, median (min-max)	6.25 (1.1–17)	8.00 (2.1–19.2)	0.107
PSAd, median (min-max)	0.08 (0.01–0.42)	0.14 (0.03–0.47)	***0.000***
Prostate Volume (cm^3), median (min-max)	89.78 (28–275)	71.64 (10–213)	***0.009***
Lesion Diameter (mm), median (min-max)	10.54 (3.0–21.0)	21.53 (12.0–48.0)	***0.000***
Lesion Volume (cm^3), median (min-max)	0.52 (0.14–4.84)	4.18 (0.90–65.4)	***0.001>***

*Current smokers and patients with any previous smoking history are accepted as (+), ** *p* values <0.05 are accepted as c

not statistically different regarding previous biopsy rates ($p = 0.401$). In univariate analysis PSA, PI-RADS score, largest lesion diameter and high lesion density were all significantly related with presence of both PCa and csPCA in cTB plus systematic biopsy ($p < 0.05$). In multivariate analysis, presence of a PI-RADS 4–5 lesion, high PSA density and high lesion density were all related with presence of csPSA ($p < 0.05$).

According to the ROC analysis, optimal cut-off value for lesion density was 0.0275. Patients were divided into two groups according to lesion density. Low-LD group had 203 patients and high-LD group had 97 patients. Groups were similar regarding smoking history, positive DRE finding and PSA values. Median age was significantly lower in Low-LD group (64.2 years vs. 65.6 years, $p = 0.048$). Prostate volume was lower and PSA density was higher in High-LD group, as expected (Table 1). More patients had 4 or higher PIRADS score in High-LD group (70.9% vs. 84.5%, $p = 0.011$) (Table 1).

Table 3 Comparison of presence of PCA and CsPCA between two groups

	Low-LD (203)	High-LD (97)	*P*
PCA %, (*n*)	32.0 (65)	53.6 (52)	0.000
csPCA %, (n)	16.7 (34)	37.1 (36)	*0.001*
MRPCA * %, (n)	17.8 (35)	43.2 (41)	*0.000*
MRcsPCA * %, (n)	11.7 (23)	30.5 (29)	*0.000*

PCA Prostate Cancer, *csPCA* Clinically significant prostate cancer, *MRPCA* Presence of PCA in MRI targeted zones, *MRcsPCA* Presence of csPCA in MRI targeted zones

* 8 patients were excluded from analysis due to lack of definitive information regarding MRI targeted cores

Presence of PCa and csPCa were significantly higher in High-LD group (32% vs. 53.6%, $p = 0.000$ and 16.7% vs. 37.1%, $p = 0001$ respectively). In the analysis of only MRI targeted cores; presence of PCa and csPCA were also higher in High-LD group (17.8% vs. 43.2%, $p = 0.000$ and 11.0% vs. 30.5%, $p = 0.000$, respectively) (Table 3).

Z-test showed significant difference for diagnostic accuracy of cTB between two groups for detection rates of PCA and csPCA in both only-targeted and combined cores ($p < 0.01$ for all parameters, Table 4).

Subgroup analysis

PIRADS 4–5 lesions

To exclude bias caused by difference in PIRADS scores between groups, we performed a subgroup analysis only including PIRADS 4–5 lesions. Total of 226 patients had PIRADS 4–5 lesions. Presence of PCa and csPCa were significantly higher in High-LD group (38.9% vs. 56.1% $p = 0.020$ and 21.5% vs. 39%, $p = 0.005$, respectively). Evaluation of only MRI targeted cores showed similar results

Table 2 Characteristics of relatively patients with relatively low and high PSA levels (3–10 & 10–20)

		PIRADS Score				
PSA 3–10 ng/mL		**2**	**3**	**4**	**5**	**Total**
PSAd	< 0.1	1	43	108	26	178
	0.1–0.15	1	8	22	8	39
	0.15–0.2	0	1	9	5	15
	> 0.2	0	0	9	6	15
Total		2	52	148	45	247
		PIRADS Score				
PSA 3–10 ng/mL		**2**	**3**	**4**	**5**	**Total**
PSAd	< 0.1	1	7	6	1	15
	0.1–0.15	0	7	4	1	12
	0.15–0.2	0	2	3	4	9
	> 0.2	0	3	7	7	17
Total		1	19	20	13	53

*Biopsy desicions for patients with low PI-RADS Score and density were based on positive DRE findings and shared desicion making

Table 4 Z-test between two groups to compare diagnostic accuracy and value of cTB

		Positive Results	Asymptotic Standard Error	Z Score	P Value
PCA	Low-LD	32%	0.033	-3.586	0.01<
	High LD	53.6%	0.051		
csPCA	Low-LD	16.7%	0.026	-3.901	0.01<
	High LD	37.1%	0.049		
MRPCA	Low-LD	17.8%	0.027	-4.633	0.01<
	High LD	43.2%	0.051		
MRcsPCA	Low-LD	11.7%	0.023	-3.945	0.01<
	High LD	30.5%	0.047		

P<0.05 represents clinical significance

Table 5 Comparison of detection of PCA and CsPCA in PI-RADS 4–5 lesions between two groups

PIRADS 4–5 Lesions	Low-ND (144)	High-ND (82)	*P*
PCA %, (n)	38.9 (59)	56.1 (46)	*0.012*
csPCA %, (n)	21.5 (31)	39.0 (32)	*0.005*
MRPCA * %, (n)	23.4 (33)	46.9 (38)	*0.000*
MRcsPCA * %, (n)	15.6 (22)	33.3 (27)	*0.002*

PCA Prostate Cancer, *csPCA* Clinically significant prostate cancer, *MRPCA* presence of PCA in MRI targeted zones, *MRcsPCA* Presence of csPCA in MRI targeted zones

* 4 patients were excluded from analysis due to lack of definitive information regarding MRI targeted cores

and both PCa and csPCA were higher in High-LD group (23.4% vs. 46.9%, $p = 0.000$ and 15.6% vs. 33.3% $p = 0.002$, respectively) (Table 5) (Fig. 1).

Zonal differences

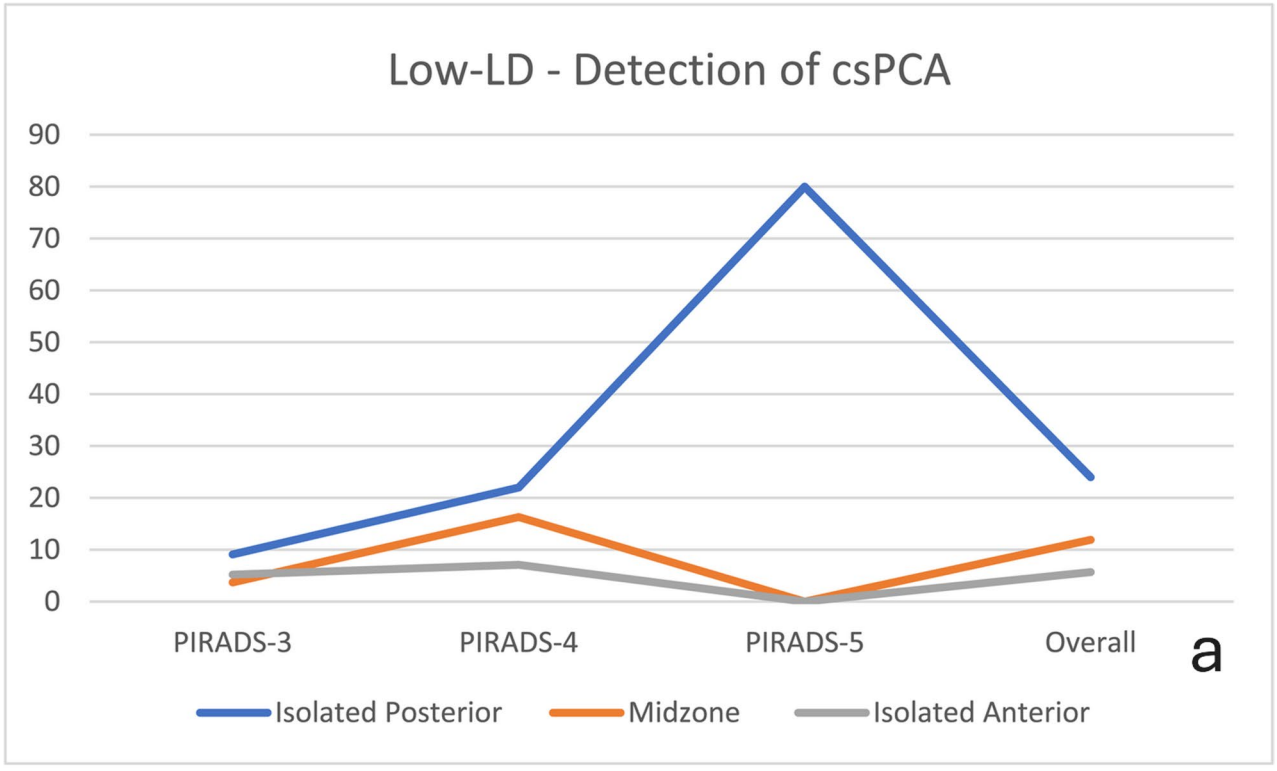
We then divided our groups into three different subgroups according to the site of the defined lesion in MRI. 84 patients had posterior zone lesions, 107 had midzone lesions and 43 had anterior zone lesions. 66 patients who had multiple zone involvement or indetermined zonal involvement had been excluded from this subgroup analysis. In Low-LD group presence of csPCA was significantly lower in anterior lesions and was highest in posterior lesions (5.7% vs. 11.9% vs. 24%, $p = 0.023$) (Table 6). As shown in Table 5, presence of csPCA for PIRADS 4–5 anterior lesions was as low as 1/16 in Low-LD group. In High-LD group presence of csPCA was higher in posterior and midzone lesions and lowest in anterior lesions (12.5% vs. 56.7% vs. 55.6%) (Table 7). Having higher lesion density still resulted in higher positive csPCa rates for all anatomic sites but presence of csPCA was found to be significantly lower for anterior lesions in both Low-LD and High-LD groups ($p < 0.05$) (Fig. 1).

Discussion

With the utilization of PI-RADS score, mpMRI have become a crucial tool in decision making for prostate biopsy. MRI targeting of suspected lesions or areas also became the standard option for PCa diagnosis. Although software assisted fusion targeting methods have been defined, cognitive fusion targeting is still widely used since it is the most costless and time-saving method for MRI targeting [13]. In spite of large-scale studies and meta-analysis reporting that saTB and cTB have similar malignancy detection rates in overall population, one can easily assume that complicating factors would impair accuracy of cognitive targeting at a higher rate.

Our results suggests that csPCa detection rates gets significantly lower with lower lesion density. We believe that evaluating the importance of both lesion size and prostate size with lesion density for cognitive accuracy is more accurate then evaluating only lesion size or prostate size, since a small needle is hard to find but even gets harder when haystack gets larger. This study is the first one to evaluate the importance of lesion density in cTB, only a handful of studies have separately evaluated the lesion size or the prostate size and reported similar outcomes [10] but no study has evaluated the importance of proportional area of a targeted lesion in prostate. Ozden et al. reported that detection of csPCA rates were significantly higher in lesions greater than 10 mm in 219 targeted biopsies [12]. It must be noted that groups were not homogenous in regards of PI-RADS score and the group with smallest lesion density mostly had PI-RADS 3 lesions. Having different higher PI-RADS scored lesions may result in a bias that leads to higher csPCA detection rates, however authors stated that in analysis of only PI-RADS 4 lesions detection rate of csPCA was significantly higher in lesions larger than 10 mm. Larger lesions tend to have higher PI-RADS score and having a larger diameter than 15 mm is differencing criteria for PI-RADS score 4 and 5 lesions [14]. Inevitably, we also had more PI-RADS score 3 lesions in the low-LD group. To overcome this bias, we also excluded the "gray lesions (PI-RADS 3)" analysed only PI-RADS 4–5 lesions in subgroup analysis. We also found out that csPCA detection rate was significantly higher in high-LD group in subgroup of PI-RADS score 4 and 5 lesions. Shao at el. have examined 74 targeted biopsies and reported that overall detection rates per lesion were similar for saTB and cTB, but saTB were more successful in lesions smaller than 13 mm [3]. Akpinar et al. compared saTB and cTB in a similar manner and concluded that saTB had higher PCa detection rates in smaller lesions and larger prostates [15].

Xu et al. evaluated the accuracy of cognitive targeting by examining post-biopsy images in a MRI-TRUS fusion workstation. They have reported that 86.1% of the lesions were accurately targeted by the senior sonographer while accuracy rate was only 69.4% for junior sonographer. They have also stated that maximum lesion length and PI-RADS score were important factors determining the accuracy of fusion targeting [16]. This finding also



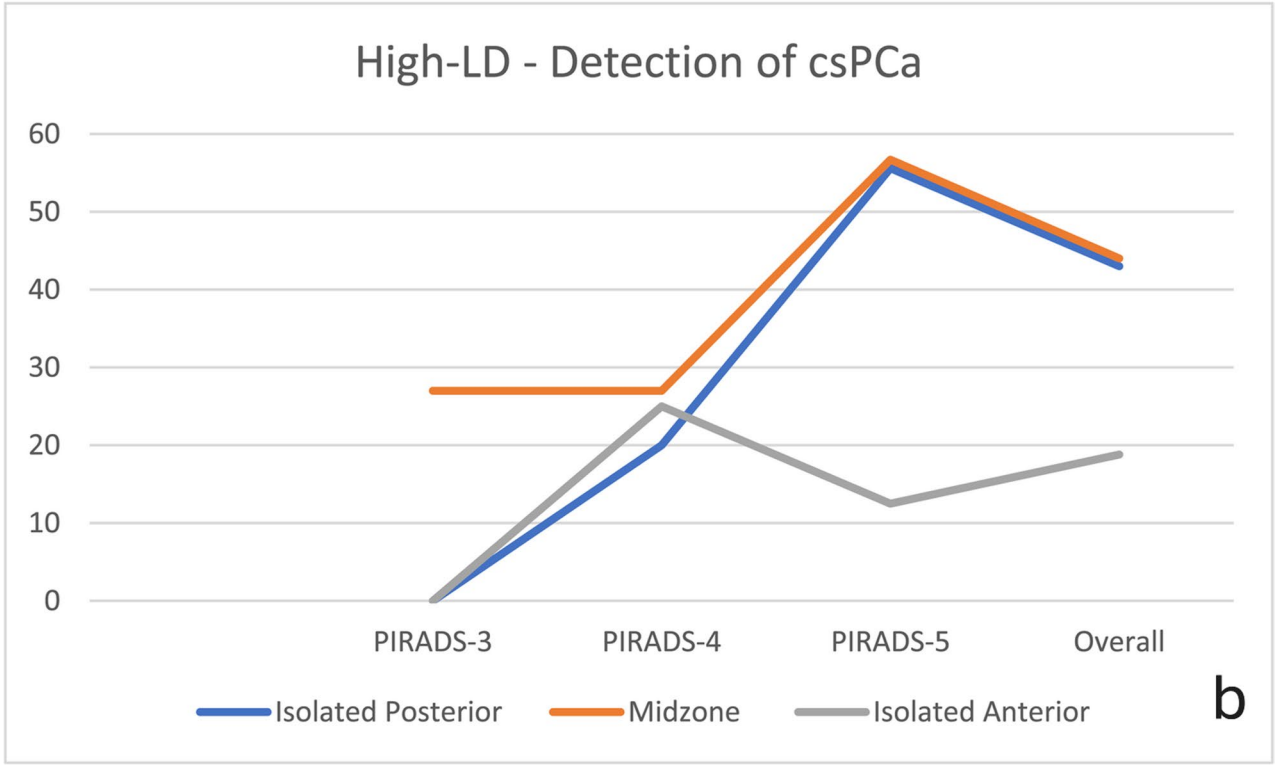


Fig. 1 **a** Detection rate of csPCA according to anatomic site and PI-RADS scores in Low-LD group, 1. **b** Detection rate of csPCA according to anatomic site and PI-RADS scores in High-LD group

Table 6 Detection rates of CsPCA in Low-LD group according to anatomic sites

Low-LD Group	Isolated Posterior	Midzone	Isolated Anterior
PIRADS-3	9.1% (1/11)	3.7% (1/27)	5.2% (1/19)
PIRADS-4	22% (13/59)	16.3% (8/49)	7.1% (1/14)
PIRADS-5	80% (4/5)	0% (0/1)	0% (0/2)
Overall	24% (18/75)	11.9% (9/77)	5.7% (2/35)

Table 7 Detection rates of CsPCA in High-LD group according to anatomic sites

High-LD Group	Isolated Posterior	Midzone	Isolated Anterior
PIRADS-3	- (0/0)	27% (3/11)	0% (0/2)
PIRADS-4	20% (1/5)	27% (3/11)	25% (2/8)
PIRADS-5	55,6% (5/9)	56.7% (17/30)	12.5% (1/8)
Overall	42.9% (6/14)	44.2% (23/52)	18.8% (3/16)

correlates with our suggestion that with a lower density, accuracy of cTB tends to decrease.

On the other hand considerable amount of large-scale studies and meta-analysis have reported that saTB and cTB are similar regarding detection of csPCA [9]. In a meta-analysis of 43 studies, authors found no significant advantage of saTB over cTB for detection of csPCA [7]. Similarly, a systematic review and a multi-centre RCT also reported that two techniques have similar detection rates [5, 6]. It must be noted that these studies were not focused on subgroup analysis for smaller lesions or larger prostates. The results of PROFUS trial also suggested that software assisted fusion targeting improves accuracy for smaller lesions [4].

Secondary goal of our study was to evaluate the importance of zonal differences since anterior lesions are harder to target in TRUS biopsies [17, 18]. csPCA detection rates were significantly low for anterior lesions in both Low-LD and High-LD groups. In anterior lesions with Low-LD detection rate for csPCA was as low as 6% (1/16), which is unacceptable for PI-RADS score 4 and 5 lesions. However, it must be noted that PCa detection rates are generally lower in transrectal approach for anterior lesions and transperineal cTB biopsy could result in higher detection rates even in low-LD group [19].

Beyond PSA and PI-RADS score, serum PSA derivatives and molecular markers may also play an important role in the diagnosis of csPCA. Free/total PSA ratio have been shown to improve diagnostic accuracy, and urinary genetic markers such as PCA3 have demonstrated complementary value for biopsy decision. In this study we have made decisions based on only PSA levels and PI-RADS score and usage of molecular markers or PSA derivates may alter the results [20]. Recently, another study implicated the emerging role of PSMA-PET in targeted biopsy setting (in patients with active surveillance) and reported higher diagnostic accuracy compared to mpMRI targeting [21]. Although usage of it is not currently common, PSMA-PET targeting may further refine patient selection for targeted biopsy.

Our study has several limitations; it is a retrospective study with no direct comparison groups to prove superiority of saTB in lower lesion density. Four different urologists performed biopsies and heterogeneity caused by clinicians may have influence in results since experience is an important factor for csPCA detection rate [22]. Another limitation is inclusion of only transrectal biopsies, transperineal approach may yield to different results especially in anterior lesions. Also, the importance of quantitative histology (positive core rate, number of positive cores, greatest percentage of PCa in cores) is not examined between groups which can be suggestive of prognosis and clinical significance [23] .To obtain higher level evidence suggesting saTB is superior in low lesion densities, direct comparison studies comparing saTB and cTB are mandatory.

Conclusion

The detection rate for csPCa is correlated with location of the lesion, operator expertise and biopsy approach. Besides its limitations our study shows that lesion density is also an important factor for csPCA detection rate in transrectal cTB. Patients with a smaller lesion, larger prostate or lower lesion density and anterior located lesions are more likely to be mistargeted and diagnosed, as false negative in transrectal cTB. saTB over transrectal cTB may be more favourable for patients with lower lesion density.

Abbreviations

csPCA Clinically significant prostate cancer
cTB Cognitive fusion targeted biopsy
PCa Prostate cancer
saTB Software-assisted fusion targeted biopsy

Authors' contributions

All authors contributed to the study conception and design. Material preparation and data collection were performed by Can Ahmet Karabacak, Ege A. Sarıkaya and M. Selcuk Ozer. Radiological evaluation was performed by Canan Altay. Analysis was performed by Ege. A Sarikaya, Burcin Tuna and Kutsal Yorukoglu. The first draft of the manuscript was written by Ege A. Sarıkaya and Volkan Sen. Revision of the manuscript was performed by Ilhan Celebi and Ozan Bozkurt. All authors read and approved the final manuscript.

Funding

The authors did not receive support from any organization for the submitted work and study was not funded by any organization.

Data availability

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request. Data are located in Dokuz Eylul University Hospital system.

Declarations

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Ethical Committee of the Dokuz Eylul University Faculty of Medicine. Written informed consent was obtained from all of the participants that involved.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 27 October 2025 / Accepted: 28 January 2026
Published online: 14 February 2026

References

1. Ferlay J, Ervik M, Lam F, Laversanne M, Colombet M, Mery L et al. Global Cancer Observatory: Cancer Today. Lyon, France: International agency for research on cancer. 2024. Available from: https://gco.iarc.who.int/to.
2. Cornford P, Tilki D, van den Bergh RCN, Eberli D, De Meerleer G, De Santis M et al. (2025). EAU Guidelines on Prostate Cancer. ISBN 978-94-92671-29-5.EAU Guidelines Office, Arnhem, The Netherlands., 2025.
3. ShaoIH, Liao FT, Chang CB, Chang YH, Wang LJ, Huang LK et al. Lesion size May affect diagnostic capabilities of MRI - guided ultrasound fusion biopsy and cognitive targeted biopsy for clinically significant prostate cancer. Sci Rep. 2024;14(1):20173. https://doi.org/10.1038/s41598-024-69661-4.
4. WysockJS, Rosenkrantz AB, Huang WC, Stifelman MD, Lepor H, Deng F, ming et al. A Prospective, blinded comparison of magnetic resonance (MR) Imaging – Ultrasound fusion and visual Estimation in the performance of MR-targeted prostate biopsy : the PROFUS trial. Eur Urol. 2014;66(2):343-51. https://doi.org/10.1016/j.eururo.2013.10.048. Epub 2013 Nov 8.
5. Watts KL, Frechette L, Muller B, Ilinksy D, Kovac E, Sankin A et al. Systematic review and meta-analysis comparing cognitive vs. image-guided fusion prostate biopsy for the detection of prostate cancer. Urologic Oncology: Seminars and Original Investigations. 2020;38(9):734.e19-734.e25.
6. WegelinO, Exterkate L, Leest M, Van Der, Kummer JA, Vreuls W, Bruin PC, De et al. The FUTURE trial: A multicenter randomised controlled trial on target biopsy techniques based on magnetic resonance imaging in the diagnosis of prostate cancer in patients with prior negative biopsies. Eur Urol. 2019;75(4):582-90. https://doi.org/10.1016/j.eururo.2018.11.040.
7. Wegelin O, van Melick HHE, Hooft L, Bosch JLHR, Reitsma HB, Barentsz JO, et al. Comparing three different techniques for magnetic resonance Imaging-targeted prostate biopsies: A systematic review of In-bore versus magnetic resonance Imaging-transrectal ultrasound fusion versus cognitive Registration. Is there a preferred technique? Eur Urol. 2017;71(4):517–31.
8. Pirola GM, Castellani D, Orecchia L, Giulioni C, Gubbiotti M, Rubilotta E et al. Transperineal US-MRI Fusion-Guided Biopsy for the Detection of Clinical Significant Prostate Cancer: a systematic review and meta-analysis comparing cognitive and software-assisted technique. 2023.
9. Puech P, Rouvière O, Renard-Penna R, Villers A, Devos P, Colombel M, et al. Prostate cancer diagnosis: multiparametric MR-targeted biopsy with cognitive and transrectal US-MR fusion guidance versus systematic biopsy–prospective multicenter study. Radiology. 2013;268(2):461–9.
10. Oderda M, Battisti G. Prostate cancer detection rate with Koelis fusion biopsies versus cognitive biopsies: a comparative study. Urologia internationalis. 2016;97(2):230–7. https://doi.org/10.1159/000445524.
11. Patel MI, Muter S, Vladica P, Gillatt D. Robotic-assisted magnetic resonance imaging ultrasound fusion results in higher significant cancer detection compared to cognitive prostate targeting in biopsy Naive men. Translational andrology and urology. 2020;9(2):601–8. https://doi.org/10.21037/tau.2020.01.33.
12. Özden E, Akpınar Ç, İbiş A, Kubilay E, Erden A, Yaman Ö. Effect of lesion diameter and prostate volume on prostate cancer detection rate of magnetic resonance imaging: Transrectal-ultrasonography-guided fusion biopsies using cognitive targeting. Turk J Urol. 2021;47(1):22–9.
13. Barrett T, Patterson AJ, Koo BC, Wadhwa K, Warren AY, Doble A, et al. Targeted transperineal biopsy of the prostate has limited additional benefit over background cores for larger MRI-identified tumors. World J Urol. 2016;34(4):501–8.
14. Turkbey B, Rosenkrantz AB, Haider MA, Padhani AR, Villeirs G, Macura KJ, et al. Prostate Imaging Reporting and Data System Version 2.1: 2019 Update of Prostate Imaging Reporting and Data System Version 2. Eur Urol. 2019;76(3):340–51.
15. Akpinar C, Kuru Oz D, Ozden E, Haliloglu N, Gulpinar B, Ibis MA et al. The role of fusion-targeted prostate biopsy in clinically significant prostate cancer detection in elusive small-diameter lesions in high-volume prostates: comparison of cognitive and fusion-targeted techniques. Urol Oncol. 2025;43(12):711.e1–7. https://doi.org/10.1016/j.urolonc.2025.08.011Urol.
16. Xu G, Xiang L, Wu J, Shao H, Liu H, Ding S, et al. The accuracy of prostate lesion localization in cognitive fusion. Clin Hemorheol Microcirc. 2020;74(3):223–9.
17. Bostancı C. Comparison of the diagnostic performance of multiparametric prostate magnetic resonance imaging results with classical parameters for prostate carcinoma in Gray zone patients. J Urol Surg. 2024;11(2):58-66. https://doi.org/10.4274/jus.galenos.2023.2023-6-17.
18. Park BK. How to improve trus-guided target biopsy following prostate mri. Cancers. 2021;13(22):5647. https://doi.org/10.3390/cancers13225647Cancers.
19. Pepe P, Garufi A, Priolo G, Pennisi M. Transperineal versus transrectal MRI/TRUS fusion targeted biopsy: Detection rate of clinically significant prostate cancer. Clin Genitourin Cancer . 2017;15(1):e33–6. Available from: https://doi.org/10.1016/j.clgc.2016.07.007
20. Pepe P, Aragona F. PCA3 score vs PSA free/total accuracy in prostate cancer diagnosis at repeat saturation biopsy. Anticancer Res. 2011;31(12):4445–9. Available from: https://www.ncbi.nlm.nih.gov/pubmed/22199313.
21. Pepe P, Pepe L, Tamburo M, Marletta G, Savoca F, Pennisi M, et al. 68Ga-PSMA PET/CT evaluation in men enrolled in prostate cancer active surveillance. Archivio Italiano Di Urol E Andrologia. 2023;95(2):31–4.
22. Brisbane WG, Priester AM, Ballon J, Kwan L, Delfin MK, Felker ER, et al. Targeted prostate biopsy: Umbra, Penumbra, and value of perilesional sampling. Eur Urol. 2022;82(3):303–10.
23. Pepe P, Fraggetta F, Galia A, Grasso G, Piccolo S, Aragona F. Is quantitative histologic examination useful to predict nonorgan-confined prostate cancer when saturation biopsy is performed? Urology. 2008;72(6):1198–202. Available from:. https://doi.org/10.1016/j.urology.2008.05.045.

Publisher's note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.