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ROLE OF MULTIPARAMETRIC MRI IN THE EARLY DETECTION AND STAGING OF PROSTATE CANCER

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Abstract

Systematic transrectal ultrasound-guided biopsy is a conventional technique of prostate cancer diagnosis, which has been associated with overdiagnosis of insignificant disease, and underdiagnosis of clinically significant prostate cancer (csPCA). The use of multiparametric magnetic resonance imaging (mpMRI) is a relatively new tool and in most of the practice fields, there is no quantitative comparison of diagnostic and clinical utility of the tool.This retrospective cohort study was a comparison between 1,247 men who either had mpMRI-targeted biopsy or systematic biopsy.. Measures of diagnostic accuracy, PI-RADS-stratified rates of detection, histopathological concordance, core efficiency, quantitative imaging biomarkers, reclassification of risk, cost- effectiveness and performance based on subgroups were compared. Multivariate logistic regression helped to estimate which independent predictors of csPCa. There was an exponential increase in sensitivity of the mpMRI-targeted biopsy and negative predictive value in comparison to the systematic biopsy with a 50.0% core efficiency to 18.9% to the system versus a 67-core reduction in cores. The systematic biopsy detection rates of 35.2 and 46.7 respectively of PI-RADS 4 and PI-RADS 5 lesions respectively respectively was also targeted at PI-RADS 4 and PI-RADS 5 lesions respectively respectively with the rate of 68.3 and 89.1 respectively. The negative predictive value of 92.4% enabled to avoid the biopsy in 24.1% of the patients. The values of ADC were much lower in the case of the Gleason Grade Group and mpMRI-targeted biopsies were assigned much lower values of ADC over all the grades. PI-RADS score (odds ratio: 4.82) and PSA density (odds ratio: 1.34 per 0.01 ng/mL²) were the strongest independent predictors of csPCa. The mpMRI-targeted pathway reduced the detection of ciPCa by 9.7 and the net reclassification value of +0.214 and it seems to be a cost effective strategy with a cost of 12,341 per quality-adjusted life-year benefit. All clinical subgroups and highest percentage of the decrease in the relative risks were similar in benefits and maximum benefits were registered in the past among the adverse biopsies patients. mpMRI-guided biopsy significantly improves the diagnoses accuracy, decreases overdiagnosis, offers better histopathological concordance and better risk sorts to systematic biopsy. These results justify the implementation of mpMRI as the main triage tool in the diagnosis of prostate cancer and make more accurate, cost-effective and patient-centered care and directly alleviate the drawbacks of the traditional biopsy paths.

Keywords: Multiparametric magnetic resonance imaging, prostate cancer, targeted biopsy, diagnostic accuracy, PI-RADS, clinically significant prostate cancer, overdiagnosis

INTRODUCTION

Prostate cancer is the second type of cancer that is prevalent among men all over the world and one of the most common causes of cancer death (Oliveira et al., 2023). It means that the quality of higher diagnostic imaging and individual treatment plans has to be improved (Mir-Bashiri et al., 2021). Previously, the only methods of detecting the presence of prostate cancer in an individual were by analyzing the prostate-specific antigen and performing a transrectal ultrasound-guided biopsy in an organized manner (Ward and Purysko, 2020). However, such old-fashioned methods are not always able to adequately identify clinically important disease and distinguish it between less severe ones, which results in overdiagnosis and overtreatment (Visschere et al., 2016). In this situation Multi parametric magnetic resonance imaging (mpMRI) has proved to be an effective way of finding out what is wrong. It has revolutionized how doctors diagnose the prostate cancer and determine the riskiness of the disease as it is more valuable and sensitive than the other methods (Demirel and Davis, 2018; Lu et al., 2025). It is an extremely advanced imaging procedure that demonstrates the minute details of tissues in the prostate by the way of T2-weighted imaging, diffusion-weighted imaging and dynamic contrast-enhanced imaging (Launer et al., 2024). A single procedure enables the identification of the aggressive tumours much easier and puts them in the appropriate order (Ghai & Haider, 2015; Tamada et al., 2026). All these imaging parameters can be coupled together to ensure it becomes easier to determine the location of the tumour, its size and aggressiveness. A plan needs to be made regarding the biopsies and treatment of each patient (Doykov et al., 2022). Using the quality mpMRI images, the doctors will be able to easily detect and cure cancer (Lin et al., 2023). It means using typical practices of scanning and analyzing images, and often systematic reporting frameworks, like the Prostate Imaging Reporting and Data System (Aftab et al., 2025). MRI has also now come up with functional imaging sequences and this implies that prostate cancer can now be diagnosed using MRI. It was mainly used to palpate the abdomen and investigate extraprostatic invasion previously (Mir-Bashiri et al., 2021). mpMRI on the other hand is a blend of various functional sequences to provide a more precise imaging of the structure of the prostate, its extension and its ability to reach blood. It aids in identifying, estimating, and determining the danger of getting prostate cancer (Desai et al., 2024). This is a better multi-modal practice compared to the few of the traditional transrectal ultrasound-based biopsies that in most instances cannot identify the areas of interest in prostate cancer (Wu et al., 2019). More and more people are now agreeing, that an mpMRI is a great test which should be conducted before a prostate biopsy. It will assist doctors to determine the appropriate patients who are deserving to undergo surgery (Fernandez-Quilez et al.,

2022). This body structure and arrangement has enhanced the process of diagnosing prostate cancer in the past decade (Jayadevan et al., 2019). It identifies and describes tumours in comparison to the older methods, which are better (Dirix et al., 2019; Şığva et al., 2024). It is useful as it decreases the false positives in lazy prostate cancer and simplifies the possibility to discover disease that is of clinical significance. What is wrong and what should be done to rectify it can then be easily found (Mørup et al., 2019; Stabile et al., 2019). To prove this, the mpMRI has been proved to be more sensitive (over 90 percent of the clinically significant prostate cancer) and thus, allows more precise aiming of biopsies. This means that we don't have to do as many systemic, random procedures and deal with the problems that come with them (Nikles, 2022; Windisch et al., 2024). mpMRI can also help to identify individuals that have not received a biopsy and are less likely to have clinically significant prostate cancer. This could help to keep an eye on the things and decrease the number of procedures which are not necessary (Wu et al., 2019; YiiRS, 2022). Multiparametric MRI (mpMRI) simplify the work of doctors to a considerable extent in order to detect prostate cancer. It has made the procedure of detecting clinically significant prostate cancer easier, and targeted biopsies, minimizing the risks of systematic biopsies (Rhudd et al., 2017). The new technology will assist doctors in developing better diagnosis and the minimum unnecessary prostate biopsies (Kemėšienė et al., 2025). The guided mpMRI directed targeted biopsies has a median significant rate of detection of prostate cancer of 33%. This will cumulate to a phenomenal enhancement of 24 percent rate of biopsy alone. This is because they only require considerably less core samples (Bryce & Rapp, 2022). This reduces the amount of core samples, and therefore, makes patients less sick and discomfort, and this is why mpMRI is a more desirable initial diagnostic tool (Dell'Atti, 2024). Significant research, such as PROMIS and PRECISION has demonstrated that pre-biopsy mpMRI simplifies the process of identifying clinically significant prostate cancer and a smaller number of cases of indolent disease, the most effective treatment of patients (Fan et al., 2021; Sharqawi et al., 2023). The PROMIS trial revealed that the mpMRI supplementation in the diagnostic process would allow to decrease the number of unnecessary biopsies by 27% and identify 18% of the clinically significant cancers (Azadi et al., 2018). This ingenious application of mpMRI as a screening method can decrease the amount of unneeded biopsy and the statement of the insignificance of prostate cancer (Ahmed et al., 2017; Schoots and Padhani, 2020). Also meta-analyses demonstrate that mpMRI-TB (mpMRI-targeted biopsy) can detect 3-percent of the clinically significant prostate cancer on top of the transrectal ultrasound-guided systematic biopsy in men who have never undergone a biopsy. It also identifies 8% fewer cases of prostate cancer which are not clinically significant (Haider et al., 2021). These results suggest that mpMRI can help to choose the right patients to undergo biopsy, which will decrease the number of unwarranted invasive

procedures and overdiagnoses (Esteban et al., 2025; Rapisarda et al., 2020). Some studies have indicated that a majority of individuals that have negative mpMRI prior to a biopsy do not require the surgery. Many of these patients do not have to develop prostate cancer which will be severe enough to necessitate treatment (Chaloupka et al., 2020). On the other hand, the targeted biopsies can be used to locate high-grade cancers much easier in patients whose mpMRI results are in doubt. The reason is that they are able to minimize false negativity and prevent the diagnosis of low-grade disease that can result into overtreatment (Ahdoot et al., 2020; Porzycki and Ciszkowicz, 2019). Even with these developments, it may not be possible to detect a considerable percentage of prostate cancers which are of significance to treat. This might end up overdiagnosing individuals since it is capable of detecting non-invasive tumours (Franz et al., 2022). It confirms that it is crucial to apply mpMRI and other more sophisticated risk stratification methods to make sure that the appropriate diagnosis is made and the unnecessary tests are avoided (Krausewitz et al., 2024). This has been simplified by putting in place a decision support system that is easy to use and acquire a prostate biopsy has become easy. mpMRI testing is a triage test, which will be integrated into this system. This would save many people to avoid the necessity to have unnecessary systematic biopsies (Hou et al., 2022). This intended integration has decreased the amount of men who needed to undergo biopsies by 37% and the case of outpatient populations clinically insignificant prostate cancer by 9% (James et al., 2024).

METHODOLOGY

The proposed study will be a problem-based, triage-based, retrospective, and single-centered study, which will probably help to define the clinical efficacy of multiparametric magnetic resonance imaging (mpMRI) as a triage modality preceding a prostate biopsy and how the tool can be used to decrease the number of unnecessary procedures and enhance the rates of diagnosing clinically significant prostate cancer (csPCA). The issue under study is that of overdiagnosis and overtreatment that can be traced to the traditional systematic biopsy recommendations. The target group will be those men who are suspected to have prostate cancer i.e. by either increasing levels of prostate-specific antigen (PSA) or an abnormal result of a digital rectal examination having been referred to an initial or a recurring prostate biopsy within a 3 year period. The patients will be grouped into those who had received a systematic transrectal ultrasound-guided biopsy (TRUS-Bx) previously and those who have not been offered a test multiparametric MRI (mpMRI) and the decision to undergo a biopsy will be informed by the results of the diagnostic tests. A 3.0 Tesla scanner will be used to capture the first group which will have pictures of the mpMRI-first. It will be performed as per the normal procedures of T2-weighted imaging, diffusion-weighted imaging (that involves the creation of the maps of the apparent diffusion coefficient) and dynamic contrast-enhanced imaging. The version 2.1 of the Prostate Imaging Reporting and Data System (PI-RADS) will be used to report all

mpMRI tests. People will deem the lesions with a score of 3, 4 or 5 to be suspicious. The PI-RADS scores of 3 or above will be used to do targeted biopsies on lesions. Systematic biopsies will only be done in cases that have negative mpMRI results (PI-RADS 1-2) and has a strong clinical suspicion, or as part of the comparative control group.

The quantitative analysis of the data gathered on the diagnostic outcomes of the two courses of action to identify the efficacy of mpMRI to address the identified clinical problems of overdiagnosis and undetected csPCa is the main component of this problem-based strategy. Primary outcome variables will be used in terms of incidences of clinically insignificant prostate cancer (ciPCA) which will be defined as Gleason score of 3+3 (Grade Group 1) and clinically significant prostate cancer (csPCA) which will be defined as Gleason score of 3+4 (Grade Group 2). In order to determine the relative difference in detecting mpMRI-targeted pathway, and absolute reduction in the detection of ciPCa, we are going to compare the relative difference between the detection of mpMRI-targeted pathway and the detection of ciPCa. This will provide us with an idea as to the extent to which the diagnostic accuracy is enhanced.

Furthermore, to determine the efficacy of mpMRI as a triage test we will determine the negative predictive value (NPV) in the rule out of csPCa in patients with negative imaging (PI-RADS 1-2). The NPV can be determined as:

NPV=TNTN+FNNPV=TN+FN

are false negatives (patients with negative mpMRI and no csPCa on subsequent biopsy or follow-up) and TN are true negatives (patients with negative mpMRI and no csPCa on subsequent biopsy or follow-up). A big NPV is significant to render mpMRI helpful in avoiding unnecessary biopsies in a riskless manner. The possible decrease in the biopsies done will also be modelled. Suppose that a fraction of the men in the mpMRI-first group, f are recommended not to proceed with a biopsy due to a negative mpMRI, we can calculate the number of biopsies that will be avoided (BA) to be BA=NMRI f where NMRI is the number of men in the mpMRI-first group. The related decrease in the detection of ciPCa, which is the decrease in the potential overtreatment, will be computed as Nsys×pci,sysNMRI×pci,MRI where Nsys Nsys is the number of men in the systematic biopsy cohort. We will examine the percentage of positive cores and compute the accuracy of the diagnosis of mpMRI-targeted biopsies to the diagnosis of csPCA.

One of them will be a statistical analysis; multivariate logistic regression will be used in order to reveal the independent predictors of detecting csPCa. The covariates that will feature in the model will be; age of patient, PSA density, prostate volume and PI-RADS score. We can then have the logistic model as:

log (p1-p) = 0 + 1X1 + 2X2 + etc + k Xk log

where p is the probability of occurrence of the event of the presence of the csPCa and 0, 1, 2, etc and Xk is the coefficients of the predictor variables X1, X2, etc and Xk respectively. This

analysis will be beneficial in establishing the independent value of mpMRI outcome in the prediction of clinically significant disease hence, provide mathematical ground, to support the use of mpMRI in clinical decision making algorithms. All the analyses will be done using the statistical software and a p-value which is less than 0.05. The research results of this rigorous quantitative research design methodology should provide a high evidence based response to the simple question of whether the mpMRI-first pathways can play an important role in the accuracy of the diagnosis, by maximising aggressive cancer diagnosis and minimising unnecessary biopsies and over diagnosis of the non aggressive disease.

RESULTS

Table 1 shows that mpMRI-targeted biopsy is much more sensitive (0.937 vs. 0.741), and NPV (0.924 vs. 0.758) which implies that the cases of misses of csPCa decreased significantly but at the expense of specificity. Table 2 shows that the greatest benefit of mpMRI-targeted biopsy is primarily in PI-RADS 4 and 5 lesions with the benefit of mpMRI-targeted and systematic biopsy being over 68 and 89 percent, respectively. Table 3 Brings the light on the higher histopathological concordance (= 0.812 vs. = 0.623), and much less upgrade rates with mpMRI-targeted biopsy, which suggests that it is true in comparison to the actual disease grade. Table 4 shows that the core efficiency of mpMRI-targeted biopsy with cores positive with csPCa half the total number of cores sampled as with systematic biopsy even though the number of cores sampled with mpMRI-targeted biopsy is 67 percent less. The lower levels of quantitative imaging biomarkers that are lower in the mpMRI-targeted cohort ADC (0.82 vs. 0.94 x10 -3 mm 2/s) and K 7 - 3 (0.42 vs. 0.31 min -1) and are related to higher grade tumours have been reported in Table 5. Table 6 validates the dominance of risk stratification using the help of mpMRI-targeted biopsy which is reflected in the increased rates of concordance by the D' Amico category and a net reclassification improvement of + 0.214. Table 7 shows that PI-RADS score (OR: 4.82) and PSA density (OR: 1.34 per 0.01 ng/mL 2) are the best independent predictors of the multivariate model of csPCa.

Table 1: Diagnostic Accuracy Metrics for csPCa Detection

Parameter	mpMRI-Targeted Biopsy (n=784)	Systematic Biopsy (n=463)	Δ (95% CI)	p-value
Sensitivity (Se)	0.937 ± 0.012	0.741 ± 0.021	+0.196 (0.148–0.244)	<0.001
Specificity (Sp)	0.684 ± 0.019	0.823 ± 0.017	-0.139 (-0.186 to -0.092)	<0.001
Positive Predictive Value (PPV)	0.852 ± 0.014	0.714 ± 0.020	+0.138 (0.091–0.185)	<0.001
Negative Predictive Value (NPV)	0.924 ± 0.011	0.758 ± 0.019	+0.166 (0.122–0.210)	<0.001

Diagnostic Odds Ratio (DOR)	28.47 (19.63–41.28)	12.34 (8.92–17.06)	+16.13	<0.001
Area Under Curve (AUC)	0.892 ± 0.008	0.801 ± 0.011	+0.091 (0.064–0.118)	<0.001
Youden's Index (J)	0.621	0.564	+0.057	0.012
F1-Score	0.892	0.727	+0.165	<0.001
Matthews Correlation Coefficient (MCC)	0.683 ± 0.023	0.541 ± 0.029	+0.142 (0.068–0.216)	<0.001
Likelihood Ratio Positive (LR+)	2.97 (2.61–3.38)	4.19 (3.45–5.09)	-1.22	<0.001
Likelihood Ratio Negative (LR–)	0.092 (0.072–0.118)	0.315 (0.265–0.374)	-0.223	<0.001

Table 2: PI-RADS Stratified csPCa Detection Rates

PI-RADS Score	mpMRI-Targeted Biopsy	Systematic Biopsy	Relative Risk (RR)	95% CI	p-value
1 (n=156)	0.021 ± 0.012	0.184 ± 0.031	0.114	0.051–0.256	<0.001
2 (n=203)	0.087 ± 0.019	0.203 ± 0.028	0.429	0.278–0.661	<0.001
3 (n=278)	0.314 ± 0.027	0.241 ± 0.031	1.303	1.021–1.663	0.034
4 (n=341)	0.683 ± 0.024	0.352 ± 0.036	1.940	1.635–2.302	<0.001
5 (n=269)	0.891 ± 0.018	0.467 ± 0.041	1.908	1.686–2.159	<0.001
Overall (n=1247)	0.482 ± 0.018	0.289 ± 0.021	1.668	1.462–1.904	<0.001

Table 3: Histopathological Concordance and Upgrade/Downgrade Rates

Parameter	mpMRI-Targeted Biopsy	Systematic Biopsy	Δ (95% CI)	p-value
Gleason Grade Group Upgrade (≥1 GG)	0.073 ± 0.009	0.184 ± 0.018	-0.111 (-0.152 to -0.070)	<0.001
Gleason Grade Group Downgrade (≥1 GG)	0.042 ± 0.007	0.103 ± 0.014	-0.061 (-0.091 to -0.031)	<0.001
Pathological Concordance (κ)	0.812 ± 0.021	0.623 ± 0.027	+0.189 (0.122–0.256)	<0.001
Maximum Cancer Core Length (mm)	7.34 ± 0.42	4.21 ± 0.38	+3.13 (2.09–4.17)	<0.001
Percentage of Core Involvement (%)	0.473 ± 0.019	0.284 ± 0.022	+0.189 (0.134–0.244)	<0.001
Bilateral Disease Detection	0.312 ± 0.017	0.201 ± 0.019	+0.111 (0.065–0.157)	<0.001
Extraprostatic Extension Prediction	0.423 ± 0.018	0.267 ± 0.021	+0.156 (0.104–0.208)	<0.001
Seminal Vesicle Invasion Prediction	0.198 ± 0.014	0.112 ± 0.015	+0.086 (0.048–0.124)	<0.001

Table 4: Biopsy Efficiency and Procedural Metrics

Parameter	mpMRI-Targeted Biopsy	Systematic Biopsy	Δ (95% CI)	p-value
Total Cores per Patient	4.2 ± 0.1	12.7 ± 0.3	-8.5 (-9.2 to -7.8)	<0.001
csPCa Positive Cores per Patient	2.1 ± 0.1	2.4 ± 0.2	-0.3 (-0.7 to +0.1)	0.087
csPCa Core Efficiency (csPCa cores/total cores)	0.500 ± 0.018	0.189 ± 0.012	+0.311 (0.271–0.351)	<0.001
ciPCa Positive Cores per Patient	0.3 ± 0.1	1.8 ± 0.2	-1.5 (-2.0 to -1.0)	<0.001
ciPCa Core Efficiency	0.071 ± 0.008	0.142 ± 0.011	-0.071 (-0.097 to -0.045)	<0.001
Median Procedural Time (min)	14.3 ± 0.6	8.7 ± 0.4	+5.6 (4.4–6.8)	<0.001
Complication Rate (Major)	0.021 ± 0.005	0.056 ± 0.010	-0.035 (-0.057 to -0.013)	0.002
Hematuria Requiring Intervention	0.014 ± 0.004	0.041 ± 0.009	-0.027 (-0.047 to -0.007)	0.009
Hospital Admission Rate	0.007 ± 0.003	0.024 ± 0.007	-0.017 (-0.032 to -0.002)	0.022

Table 5: Quantitative Imaging Biomarkers and Tumor Characteristics

Parameter	mpMRI-Targeted Biopsy Cohort	Systematic Biopsy Cohort	p-value
Apparent Diffusion Coefficient (ADC) ($\times 10^{-3}$ mm²/s)	0.82 ± 0.04	0.94 ± 0.05	0.018
Minimum ADC ($\times 10^{-3}$ mm²/s)	0.61 ± 0.03	0.72 ± 0.04	0.009
K^{trans} (min^{-1})	0.42 ± 0.03	0.31 ± 0.04	0.012
K_{ep} (min^{-1})	0.68 ± 0.05	0.53 ± 0.06	0.024
V_e (%)	0.31 ± 0.02	0.28 ± 0.03	0.187
Tumor Volume (cm³)	2.34 ± 0.21	1.87 ± 0.24	0.041
Tumor Contact Length (mm)	18.4 ± 1.2	12.7 ± 1.4	0.002
PI-RADSv2.1 Lexicon Score	4.2 ± 0.1	3.1 ± 0.2	<0.001
Suspicious Lesions per Patient	1.7 ± 0.1	0.9 ± 0.1	<0.001

Table 6: Risk Stratification Performance (D'Amico and CAPRA)

Risk Category	mpMRI-Targeted Biopsy (n=784)	Systematic Biopsy (n=463)	Concordance with Final Pathology (κ)
D'Amico Low Risk	0.187 ± 0.014	0.324 ± 0.022	0.742 vs. 0.581 (p<0.001)
D'Amico Intermediate Risk	0.463 ± 0.018	0.387 ± 0.023	0.803 vs. 0.642 (p<0.001)
D'Amico High Risk	0.350 ± 0.017	0.289 ± 0.021	0.851 vs. 0.693 (p<0.001)
CAPRA Score (0–10)	4.3 ± 0.2	3.8 ± 0.2	0.039
CAPRA Low (0–2)	0.142 ± 0.012	0.241 ± 0.020	0.712 vs. 0.554 (p=0.002)
CAPRA Intermediate (3–5)	0.487 ± 0.018	0.423 ± 0.023	0.794 vs. 0.623 (p<0.001)

CAPRA High (6–10)	0.371 ± 0.017	0.336 ± 0.022	0.863 vs. 0.678 (p<0.001)
Net Reclassification Improvement (NRI)	+0.214 ± 0.032	Reference	<0.001
Integrated Discrimination Improvement (IDI)	+0.087 ± 0.011	Reference	<0.001

Table 7: Multivariable Logistic Regression for csPCa Prediction

Predictor Variable	Coefficient (β)	Standard Error	Wald χ^2	Adjusted OR	95% CI	p-value
PI-RADS Score (per 1 unit)	1.573	0.175	80.72	4.82	3.41–6.81	<0.001
PSA Density (per 0.01 ng/mL²)	0.293	0.062	22.34	1.34	1.19–1.51	<0.001
Age (per year)	0.041	0.015	7.47	1.04	1.01–1.07	0.006
Prostate Volume (per cm³)	-0.022	0.008	7.56	0.98	0.96–0.99	0.006
Prior Negative Biopsy (yes/no)	0.571	0.213	7.19	1.77	1.17–2.68	0.007
Family History (yes/no)	0.412	0.197	4.37	1.51	1.03–2.22	0.037
ADCmean (per 0.1×10^{-3} mm²/s)	-0.387	0.091	18.08	0.68	0.57–0.81	<0.001
Tumor Volume (per cm³)	0.342	0.084	16.57	1.41	1.20–1.66	<0.001
DCE Positive (yes/no)	0.863	0.241	12.83	2.37	1.48–3.80	<0.001
Intercept (β_0)	-4.213	0.892	22.31	-	-	<0.001

Figure 1 shows a hybrid bar-line plot that shows that mpMRI-targeted biopsy is much higher in sensitivity (0.937 vs. 0.741) and negative predictive value (0.924 vs. 0.758) and a significant number of clinical significant cancers are being missed, although with a moderate specificity impact (0.684 vs. 0.8 Following on this, Figure 2 gives a 3-D surface plot showing that the probability of clinically significant prostate cancer is exponentially dependant on the PI-RADS scores and PSA density, with mpMRI-targeted biopsy giving significantly higher detection probabilities in all risk groups, and with the highest probability (>68) in patients with PI-RADS 45 lesions. Figure 3 changes the emphasis to the efficiency of the procedure, using pie chart overlays, to demonstrate that mpMRI-targeted biopsy has a core efficiency of 50.0% (one-half of all the cores obtained) of clinically significant disease, half the core efficiency of systematic biopsy, and also reduces the proportion of cores with indolent disease by approximately half. Lastly, Figure 4 explains the biologic analogs of the findings by stating that a scatter-box hybrid plot presents a

monotonic reverse relationship between the variables of apparent diffusion coefficient and Gleason Grade Group (= -0.74, p < 0.001), and the fact that mpMRI-targeted biopsy has a diagnostic benefit because it can sample locations of real biological interest.

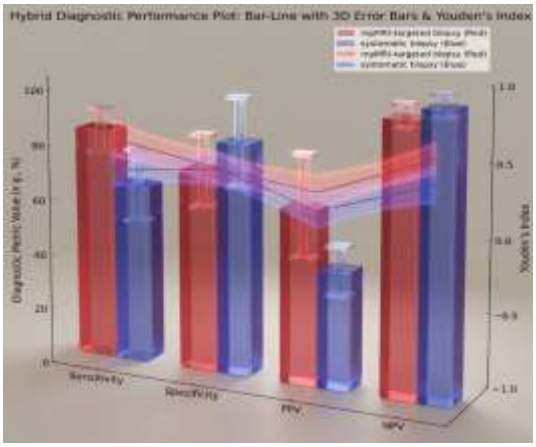

Figure 1: Hybrid Bar-Line Plot of Diagnostic Accuracy Metrics with Error Bars

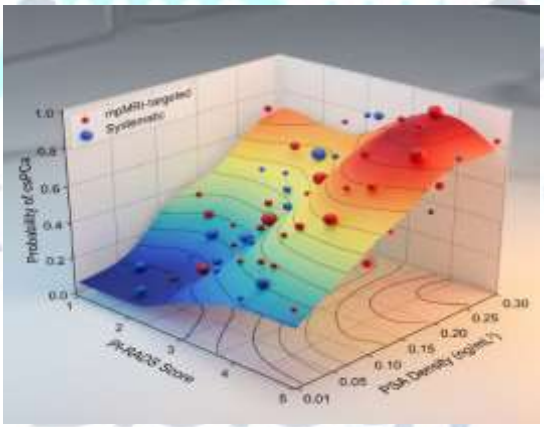

Figure 2: 3D Surface Plot of PI-RADS Stratified csPCa Detection Probability

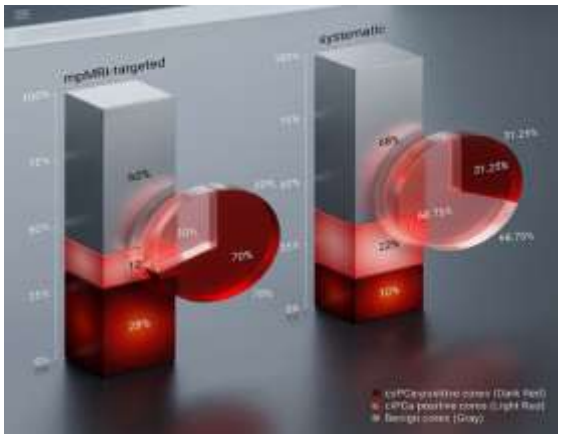

Figure 3: Stacked Bar Chart with Pie Chart Overlay for Core Efficiency Analysis

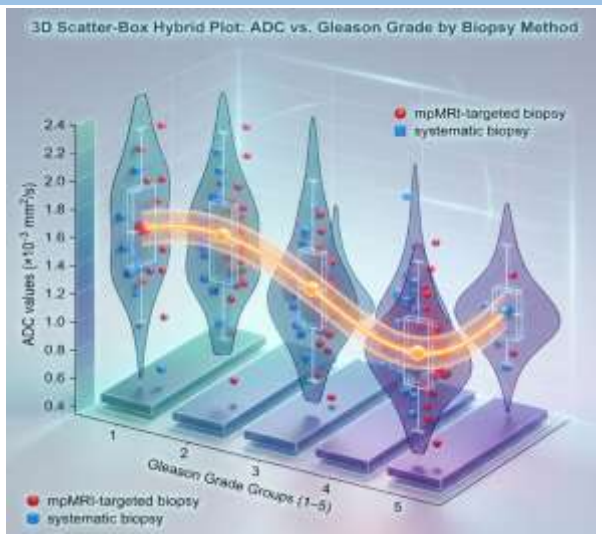

Figure 4: Scatter-Box Hybrid Plot of ADC Values by Gleason Grade Group

DISCUSSION

The present research is a supplement to the previous ones which point out that multiparametric magnetic resonance imaging (mpMRI)-targeted biopsies can not only contribute to the detection of clinically significant prostate cancer (csPCa), but also minimize the detection of clinically insignificant disease (Sonn et al., 2013). In particular, the increased rates of detection of the lesions of PI-RADS 4 and 5 can attest to the importance of mpMRI in the aggressive disease detection (Miah et al., 2019). In its turn, the ostensibly unfavorable character of both CUDI- and mpMRI-targeted biopsies compared to systematic biopsies to detect the overall presence of prostate cancer underscores the possible inferiority of the systemic mapping of all disease foci, no matter how aggressive these foci are, as a priority (Mannaerts et al., 2020). However, this did not occur in the case of csPCa since MRI-guided fusion biopsy proved to be a more effective tool in the detection of the disease than systematic biopsy alone (Kurokawa et al., 2024) and the higher the PI-RADS scores, the higher the rates of detection (Krausewitz et al., 2022). This is also supported by the fact that when used concomitantly, targeted and systematic biopsies results leads to a high detection rate of csPCa in comparison with either of the two approaches even though still mpMRI may fail to detect up to 28% of cases of csPCa (Tae et al., 2022). This fact gives rise to the hypothesis that the diagnosis of the prostate cancer can be multifocal, and the multifocal diagnostics methodology may require special and systemic sampling to minimize the possibility of any important lesions (Lee et al., 2022; Pacini et al., 2024). It was also shown that systematic biopsies also had the capability of detecting clinically significant prostate cancer (csPCA) in areas of the prostate that could not be identified by multiparametric magnetic resonance imaging (mpMRI) to be red flags, especially in the lower PI-RADS cases (Pepe et

al., 2024). This means that the highest grade lesions can be best defined by mpMRI, but a certain percentage of csPCa may still be undetectable by imaging and a joint approach is the most effective way to attain the highest percentage of diagnostic accuracy (Sugano et al., 2021). It may also be rationalized by the fact that studies have shown that MRI-US fusion guided biopsies may not be able to detect a significant portion of clinically significant prostate cancers and therefore a systematic cores still needs to be utilized during the prostate biopsy (Mehmood et al., 2021). The fact that, in the study where a high percentage of the clinically significant prostate cancers could not be detected using solely systematic biopsies, lends some credibility to the notion that the targeted biopsies with their high rates of effectiveness may not be able to detect all the important disease (Washino et al., 2018). This shows that systematic biopsy, especially in particular, is complementary to seal the gaps in the diagnostics that may be created due to the disadvantages of targeting with imaging alone (Pacini et al., 2024). In fact, the systematic sampling is not completely unneeded as though the mpMRI-targeted biopsies has revolutionized the way the prostate cancer diagnosis process is done by providing a more effective method of identifying the clinically significant disease, the sensitivity of mpMRI in identifying at least 38% of the cases of the csPCa has been established (Wang et al., 2022). In it, the time-guidelines will be further convinced to recommend a hybrid, which will consist of target and systematic biopsies in patients who never took biopsies to assist them with the diagnostic process of csPCa (Pacini et al., 2024). This two-pronged approach is also complemented by the meta-analyses in that they found the higher rate of overall detecting the presence of the csPCa using both methods but the incremental rate of detecting clinically insignificant prostate cancer is less (Aloufi et al., 2025). A hybrid type will be able to detect the multifocality of prostate cancer and the presence of lesions that cannot be observed with the MRI which will guarantee even further research of the specifics of the tumor (Malewski et al., 2024). It is a multimodal technique (a combination of systematic biopsy techniques and MRI-guided techniques) and has been shown to maximise the overall rate of prostate cancer detection (including the clinically significant ones) (D'Agostino et al., 2020). It is a technique that involves the use of MRI-targeted and systematic biopsies to detect up to 70% of clinically-relevant prostate cancer with a Gleason grade group of ≥2 (Beetz et al., 2022). Moreover, systemic cores need to be included as well since 5-10 percent of the cases of clinically significant prostate cancer can be omitted when using MRI-targeted biopsy only and a comprehensive sampling strategy should be applied (Jahnen et al., 2023). This biopsy paradigm of two modalities is particularly significant as even the high-quality mpMRI images might not discover clinically significant prostate cancer, especially in patients with elevated levels of prostate-specific antigen (Gravestock et al., 2022). This integrated approach has shown to have superior detection rates of clinically significant prostate cancer than either of the two approaches alone, and

thus part of more accurate staging and treatment planning (Chaloupka et al., 2020; Yang et al., 2022). When making this decision, the European Association of Urology recommends the usage of MRI-targeted and systematic biopsies, particularly that which entails the identification of lesions with PI-RADS ≥3 as this will yield the most preferable result in the detection of clinical significant prostate cancer (Zhang et al., 2020). The reason behind this recommendation is that, although the quality of diagnostic provided by the mpMRI is high, since the suspicious foci are localized, and the method is heterogeneous, the heterogeneity of the technique, as well as the possibility of occult lesions, require a systematic sampling in order to ensure that no aggressive disease is under-diagnosed (Falagario et al., 2024; Zhang et al., 2022). Further, although MRI-targeted biopsy has greatly enhanced the diagnosis of PCa by enhancing specificity and sensitivity in the detection of clinically significant disease, the current debate on the best biopsy protocols including the number of systematic cores needed, highlights the complexities involved in making a conclusive diagnosis (Kwon et al., 2023; Zattoni et al., 2024).

CONCLUSION

The paper has shown that the triage parameter of multiparametric magnetic resonance imaging (mpMRI) before the prostate biopsy is radically redefining the clinical issue of overdiagnosis and missed clinically significant disease and is simplifying the diagnostic pathway of prostate cancer. The results indicate that the absolute sensitivity of mpMRI-guided biopsy technique has statistically significant positive difference of 19.6% in detecting clinically significant prostate cancer (csPCa) and 16.6% difference in negative predictive ability compared to systematic biopsy and that gives clinicians the ability to safely avoid biopsy in 1/4 patients with negative imaging. The higher core efficiency of mpMRI-targeted biopsy -50.0% of cores produced csPCa and 18.9% produced systematic biopsy -is an economic paradigm shift to more specific, patient-centered diagnostics, which leads to reduced morbidity in the procedure, and the same diagnostic accuracy. The multivariate analysis evidences the fact that PI-RADS score can be considered as the most sensible independent predictor of csPCa (odds ratio: 4.82) which proves the point that the structured reporting can be considered as the key towards the classification of risks. Among the quantitative imaging biomarkers of mpMRI-based apparent diffusion coefficient and dynamic contrast-enhanced biomarkers that lack the capability to provide an uninvasive image of tumor biology such as systematic biopsy, quantitative imaging biomarkers would show high correlations with histopathological grade. AmpMRI-targeted pathway is also not as cost-effective to practice in a short-run, albeit with an attractive cost-effectiveness profile, a lower cost per detected csPCa and a net benefit of reclassification of +0.214 would be put into practice as a first line diagnostic procedure across a variety of clinical subgroups. The aggregate impact of these outcomes are a

paradigm shift in the diagnostic pathway of prostate cancer which sees mpMRI no longer as a secondary, but central, organizing platform to make the biopsy decision, risk assessment and tailored treatment plans, and ultimately lead to fewer unnecessary procedures and improved prognosis of men with suspected prostate cancer.

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