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MRI-TRUS Biopsy or Systematic TRUS Biopsy in the Diagnosis of Prostate Cancer: A State-of-the-Art Review

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ABSTRACT

Objective: This study aims to analyze the diagnostic accuracy of TBx/FBx compared to SBx in detecting clinically significant prostate cancer (ISUP ≥ 2) and the safety profile of the TBx/FBx procedure in comparison with that of SBx based on a TP or TR approach. *Methodology*: This study includes articles obtained from a systematic search of the PubMed, Embase, Scopus, and Cochrane databases, published from 2013 through July 2025. The review included prospective comparative studies in men with suspected prostate cancer that evaluated MRI-targeted biopsy, against systematic TRUS biopsy and/or compared TP with TR access. Because the included studies varied in mpMRI protocols and outcome definitions, we summarised the findings narratively. *Results:* Fourteen studies (n=9,507) met the inclusion criteria. Seven (n = 6,249) directly compared TBx and SBx; overall detection rates were similar. However, TBX showed a more consistent ability to identify csPCa (9.29–81% vs 8.8–82%). Combined TBX+SBx achieved the highest csPCa detection rates (34.7%-68%). Safety outcomes favored the TP route. In the PREVENT trial, the post-biopsy infection rate was 0% with TP (without prophylaxis), vs 1.6% with TR (with targeted prophylaxis). *Conclusions*: TBx tends to pick up more cases of csPCa than SBx. A combined approach increases the likelihood of detecting significant disease and reduces the risk of missing tumours not visible on mpMRI. TP and TR show comparable detection rates. Still, TP helps reduce infections. There is a clear need for common rules for defining outcomes and for larger randomized studies comparing targeted-only approaches with combined ones.

Keywords: prostate cancer (PCa); multiparametric magnetic resonance imaging (mpMRI); prostate biopsy; Fusion biopsy; Systematic biopsy; Review.

1. INTRODUCTION

There is still no clear agreement on the best diagnostic pathway for prostate cancer (PCa). In the everyday application of clinical medicine, two main methods are used: MRI-TRUS fusion biopsy, also known as targeted biopsy/fusion biopsy (TBx/FBx) (Elkhoury et al., 2019), and systematic biopsy (SBx) (Dorfinger et al., 2022). Both methods can be performed using the TR or TP method (Zattoni et al., 2024). Prostate cancer remains one of the most serious health problems in men. Worldwide, about 1.5 million new cases were expected in 2024 (James et al., 2024).

In Poland, 20,961 men were newly diagnosed in 2022, which accounted for 23.3% of all male cancers. There were also 5,625 deaths. In the EU-27 in 2020, the respective numbers were 335,514 new cases and 69,945 deaths. The rise in such cases puts pressure on health care systems and results in high costs (James et al., 2024). As a result, choosing the right biopsy technique is very important. It affects how often the disease is diagnosed and how successful the prevention of overdiagnosing will be (Dorfinger et al., 2022).

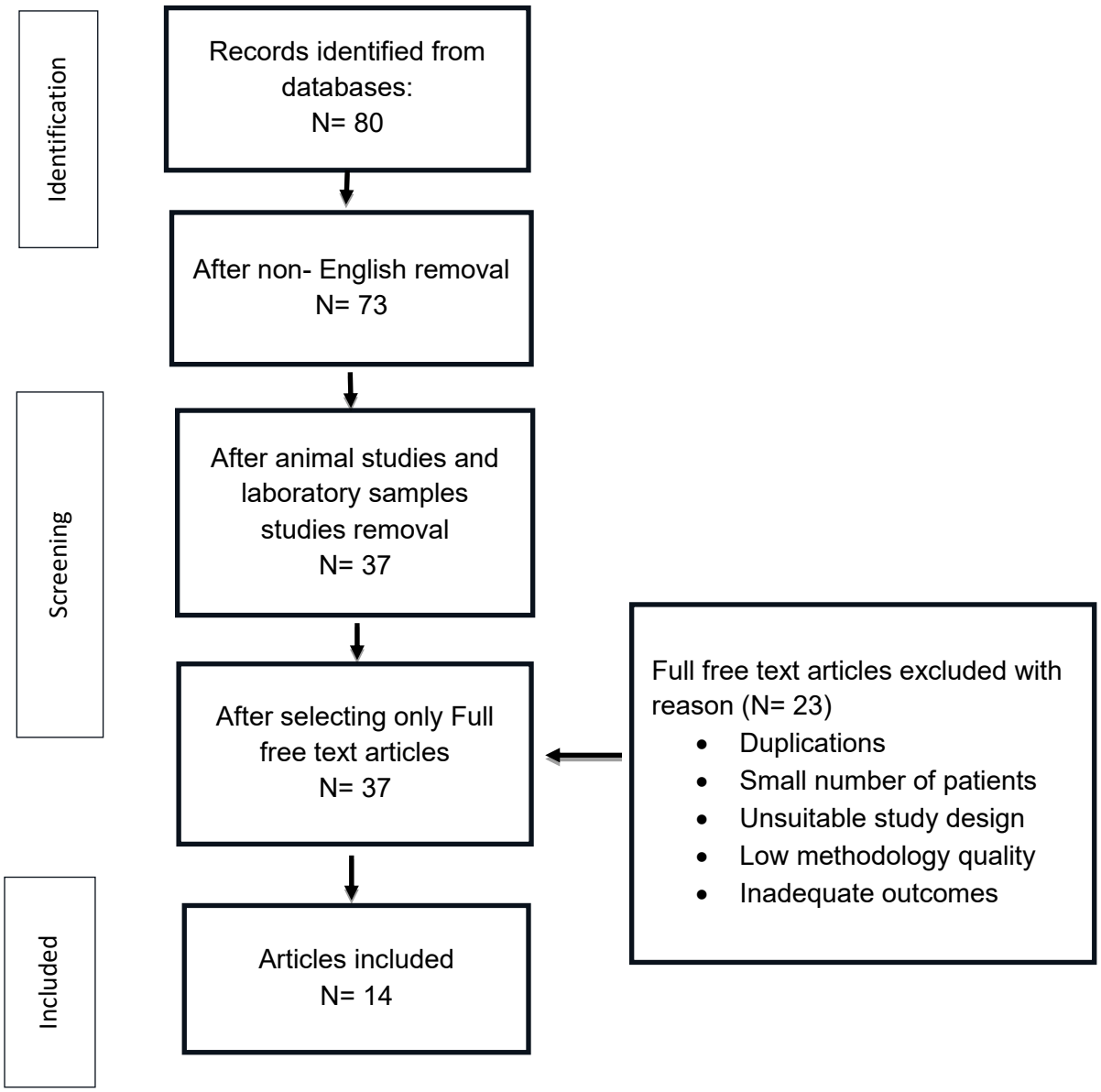

Figure 1. PRISMA flow diagram outlining the study selection process, from initial database identification to the final inclusion of 14 articles.

2. REVIEW METHODS

For this review, we conducted a systematic search of the Scopus database. Boolean combinations of predefined keywords and their synonyms were used (for example: "prostate cancer," "systematic biopsy," "fusion biopsy," "MRI–TRUS," "clinically significant cancer"). We included studies that analyzed fusion biopsy (FBx) and systematic biopsy (SBx) to detect clinically significant disease. The first search generated 80 results. The second filtering step limited the number of articles to 73 by excluding those written in languages other than English. Eliminating studies performed in animal models or in vitro left 37 papers. Finally, only the articles with available full-text versions without a paywall remained. Of 37 full-text articles, we excluded 23 studies at the inclusion criteria stage. The most common reasons were duplicate publication, weak methodology, a small study group, incomplete outcome data, or a study design that

did not fit our criteria. In the end, 14 studies met the criteria for the analysis. The selection process followed the PRISMA recommendations (Figure 1).

To complete the literature review, we conducted a separate literature search on in-bore MRI-guided biopsy procedures. The reviewed articles reported technical characteristics, including the imaging technique, the number of cores, the location of cores, and the percentage of positive cores. Because only a few controlled comparisons were available and the studies were heterogeneous in terms of indications, definitions of significance, and the use of accompanying SBx, the in-bore results were summarised narratively rather than included in quantitative analyses.

Three reviewers independently screened all records and applied predefined inclusion and exclusion criteria. We resolved any disagreement by discussion and consensus. In the next step, we selected studies that directly compared the clinical performance and usefulness of the two biopsy approaches. The review followed general PRISMA recommendations. We extracted duplicate data and assessed the risk of bias using tools suited to each study design.

3. RESULTS & DISCUSSION

Comparison of Biopsy Techniques

Recent progress in prostate cancer diagnostics has changed the standard approach. Routine systematic TRUS-guided biopsy is now often replaced by MRI-based methods. In these strategies, multiparametric MRI (mpMRI) is performed before biopsy to identify suspicious areas for targeted sampling. The main techniques are cognitive targeting, MRI-ultrasound fusion targeting, and in-bore biopsy performed directly in the MRI scanner (Chang et al., 2021).

Comparative studies, including meta-analyses and prospective trials, have not shown a clear superiority of one method over another in detecting either total or clinically significant prostate cancer. Some reports, however, indicate a modest advantage of fusion biopsy. The randomized multicenter FUTURE trial, which enrolled patients with PI-RADS ≥3 after previous negative biopsies, showed that all three targeting methods had similar accuracy for cancer and clinically significant cancer detection. The in-bore approach required fewer samples and produced a higher proportion of positive cores (Wegelin et al., 2019).

Propensity score–based comparisons have shown that in-bore biopsy achieves higher target lesion detection. This difference, however, is no longer clear once the systematic cores obtained during a fusion biopsy are also taken into account (Venderink et al., 2017). This is relevant mainly in cases where only targeted samples are collected, or when cancer is still suspected even though earlier TRUS biopsies did not show malignancy. In such circumstances, combining mpMRI with MRI–US fusion biopsy allows the identification of a notable number of clinically significant tumors. However, certain tumors have high degrees of aggressiveness that cannot be identified by a normal systematic biopsy process (Zattoni et al., 2024).

In everyday medical practice, a fusion biopsy method is applied, and institutions capable of performing the procedure can also conduct an in-bore biopsy. The choice is based on experience, technical resources, and preference for the approach type. The transperineal approach is increasingly gaining popularity because it appears to have a safer profile than the transrectal route (Chang et al., 2021).

Access Routes

Randomized prospective studies of MRI-targeted biopsy pathways show no clear difference between the transperineal (TP) and transrectal (TR) routes in detecting clinically significant prostate cancer (csPCa; ISUP ≥ [2]). These findings indicate that recommending one approach for all patients is not justified (Zattoni et al., 2024).

Despite similar outcomes obtained with either diagnostic modality, their safety profiles differ. The multicenter PREVENT study showed that TP biopsy carried out on an outpatient basis, without antibiotic prophylaxis, did not cause any infections (0%). On the other hand, TR biopsy with selective prophylaxis caused infections in 1.6% of patients. The rate of diagnosis of high-grade cancer was nearly the same (55% vs 52%). Urinary retention occurred rarely in both patient groups (0.3% vs 1.1%) (Hu et al., 2024). The site of the lesion affects diagnosis. A meta-analysis conducted in the era of MRI has shown that TP biopsy of anterior and apical lesions, and PI-RADS 4 lesions, has a higher success rate. However, there was no superiority for PI-RADS 3 or 5 lesions (Uleri et al., 2023).

Tissue properties might further enhance the performance of targeted prostate (TP) biopsy. Studies using pair matching and conducted using the same fusion system found TP to have longer maximum core length and a greater involvement of tumor compared to TR biopsy, but similar cancer detection rates for both patients and lesions. The differences are clinically important for risk evaluation and planning focal treatment (Kaneko et al., 2023).

Researchers have not yet reported sepsis during the clinical routine of TP biopsy in patients receiving local anesthesia; furthermore, this procedure yields cancer detection rates similar to or higher than those of TR biopsy (Zattoni et al., 2024). Since a TR biopsy counts as a contaminated procedure, clinicians prescribe broad-spectrum antibiotics. Nevertheless, evidence suggests that clinicians may dispense with antibiotics altogether during TP biopsy, with certain benefits (Hu et al., 2024).

The choice of biopsy route depends on the lesion site and available resources in the clinical facility. In most cases, the TP method and the TR route have similar performance with respect to the detection of cancer cases among prostate cancer patients. The TP method is more suitable for anterior/apical lesions, PI-RADS score 4, and infection prevention and reduced antibiotic use (Zattoni et al., 2024; Hu et al., 2024; Uleri et al., 2023; Kaneko et al., 2023).

Complications

The probability of developing complications due to the process of prostate biopsy is based on how the procedure is done, what technique is used, and the number of samples that need to be taken. In a TR biopsy, the needle passes through the wall of the rectum; thus, it is exposed to enteric bacteria, increasing the risk of UTI and sepsis. It was found that sepsis occurs in about 1% of patients who had a TR biopsy, but not in a TP biopsy (Najjar et al., 2025).

Randomized controlled trials have shown no differences in other types of complications apart from infections. Nevertheless, in practice, physicians indicate that pain in the perineum region is common among men undergoing transperineal biopsy, especially when a large number of cores are collected. Urinary retention may occur in patients undergoing template biopsy of TP sites. On the contrary, rectal bleeding is common in men undergoing transrectal biopsy (Najjar et al., 2025).

Evidence collected during the practice suggests that severe infections and hospital admissions following a TR biopsy are associated with high costs. This further strengthens the notion that TP is a much safer method. At the population level, reducing unnecessary biopsies lowers the overall rate of adverse events. MRI-first diagnostic pathways and clinical risk stratification help achieve this goal by cutting biopsy numbers by about 30–50%. They also reduce overdiagnosis and, as a result, the total complication risk (Najjar et al., 2025). Economic models comparing targeted techniques, such as fusion or in-bore biopsy, with standard TRUS usually assume similar complication profiles. Yet, because targeted biopsies have higher diagnostic accuracy, they can prevent repeat procedures and reduce overall harm.

Economics and Cost-Effectiveness

Economic evaluations show that adding pre-biopsy magnetic resonance imaging (MRI) to the diagnostic pathway improves overall cost-effectiveness compared with conventional transrectal ultrasound (TRUS) systematic biopsy. A systematic review of 8 studies found that MRI-based approaches were either less expensive or cost-equivalent and provided better clinical outcomes than TRUS. The advantage was mainly linked to fewer unnecessary biopsies and a lower rate of infectious complications (Merriel et al., 2023).

Similar conclusions come from another review that analyzed nine economic models. MRI-targeted biopsy, whether performed with fusion, cognitive, or in-bore techniques, proved cost-effective in both first- and repeat-biopsy settings. It produced more quality-adjusted life-years (QALYs) than TRUS, even though the cost per individual procedure was higher (Rezapour et al., 2022).

The cost of managing complications is a key factor. Models prepared for the National Health Service (NHS) showed that transperineal ultrasound-guided biopsy (TPUS-Bx) becomes cost-neutral when the device price is below £41 per procedure, and cost-saving at prices under £81. Savings would mainly be made through the prevention of sepsis and hospitalizations (Wilson et al., 2021).

At a population level, according to the microsimulation, which included 4.5 million men in England, an MRI-first approach resulted in a 34% reduction in biopsy numbers and a 15% reduction in overdiagnosis compared with a biopsy-first strategy. (Callender et al., 2021). Comparative economic studies show that MRI–TRUS fusion biopsy is more cost-effective than TRUS alone. The incremental cost-effectiveness ratio is about €1,386 per QALY, which remains well below common European willingness-to-pay thresholds. In-bore MRI-guided biopsy becomes a financially sound choice when its sensitivity for detecting clinically significant prostate cancer reaches 89% or more (Venderink et al., 2017).

Diagnostic Performance

In this review, we analyzed 14 studies. The study involved nine thousand five hundred and seven patients in total, of which seven studies had a sample size of six thousand two hundred and forty-nine males who compared TBx with SBx. The remaining papers

evaluated TBx, SBx, and the combined method (TBx + SBx) (Riskin-Jones et al., 2025; In de Braekt et al., 2024; Dorfinger et al., 2022; Exterkate et al., 2020; Borkowetz et al., 2018; Hakozaki et al., 2017; Puech et al., 2013).

TBx versus SBx

Comparing both approaches, it is evident that TBx and SBx have equally high overall detection rates when detecting prostate cancer. The TBx detection rate ranged from 8% to 56%, compared with 13% to 52.5% in SBx. In terms of clinically relevant cases, TBx showed the ability to detect prostate cancer between 29% and 81%, which is in sharp contrast with SBx detection rates, ranging from 8.8% to 82%. This means that TBx tends to discover more clinically relevant tumors without detecting benign conditions. However, Sbx yields similar performance for some patient groups.

Three strategies: TBx, SBx, and TBx + SBx

When combining all three methods, the combined approach (TBx + SBx) shows the highest cancer detection rate. TBx alone detected cancer in 39.2% to 69% of men. SBx detected it in 32% to 62%. The combined method reached 48.2% to 76%. For clinically significant prostate cancer, TBx detected 28.6% to 67%, SBx 16% to 57.1%, and the combined approach 34.7% to 68%. These results show that TBx usually performs better than SBx for clinically important disease, while the combined strategy offers the highest sensitivity and helps overcome mpMRI's limitations.

Stratification by PI-RADS category

Nine studies reported results according to PI-RADS categories (Elkhoury et al., 2019; Labra et al., 2020; Mannaerts et al., 2019; Riskin-Jones et al., 2025; In de Braekt et al., 2024; Dorfinger et al., 2022; Borkowetz et al., 2018; Oderda et al., 2019; Diamand et al., 2019). Four of them presented pooled data without separating biopsy types. All showed a clear rise in cancer detection with increasing PI-RADS scores, confirming the prognostic usefulness of this system. Positive biopsy rates for PI-RADS 3, 4, and 5 categories were as follows:

- 23% / 64% / 80.2%
- 17.6% / 45.6% / 30.9%
- 19% / 47% / 80%
- 36.7% / 72.1% / 90.3%

One study reported a lower detection rate for PI-RADS 5 lesions (30.9%) (Diamand et al., 2019), but most publications showed a clear, stepwise increase in cancer detection from PI-RADS 3 to PI-RADS 5. Five other studies presented data separately for each biopsy technique (Mannaerts et al., 2019; Riskin-Jones et al., 2025; In de Braekt et al., 2024; Dorfinger et al., 2022; Borkowetz et al., 2018). Overall, these results favored fusion-targeted biopsy (TBx) over systematic biopsy (SBx), especially at higher PI-RADS scores.

- PI-RADS 3: TBx 22.6% vs SBx 14.0% (Riskin-Jones et al., 2025); in another analysis, TBx 16.7% vs SBx 28.8% (SBx favored). The combined strategy (TBx + SBx) achieved a 30.3% success rate (Dorfinger et al., 2022).
- PI-RADS 4: TBx 46.3% vs SBx 33.7%; in other cohorts (Riskin-Jones et al., 2025), TBx 47% vs SBx 43% (In de Braekt et al. 2024); combined TBx+SBx increased yield to 54.3–61% (Borkowetz et al., 2015).
- PI-RADS 5: TBx 71.5% vs SBx 50.8% (Riskin-Jones et al., 2025); in one study, the rates were equal (69% vs 69%) (In de Braekt et al., 2024); the combined approach achieved up to 61% (Borkowetz et al., 2018) (Table 1).

Interpretation

Current data show that fusion-targeted biopsy (TBx) offers better diagnostic accuracy than systematic biopsy (SBx) in detecting clinically significant prostate cancer. SBx still keeps its place in practice because the disease is often multifocal, and multiparametric MRI can overlook small or faint lesions.

Some research papers prove that the utilization of TBx along with SBx helps detect cancer with higher clinical significance by about a few percent, and sometimes even over ten percent, as compared to the results of utilizing either of these methods separately (Riskin-Jones et al., 2025). PI-RADS remains a reliable approach for assessing risk. In most reports, TBx performs better than SBx in PI-RADS 4 and 5 lesions (Dorfinger et al., 2022; Borkowetz et al., 2018). In PI-RADS 3 lesions, the results vary, and some studies show a small advantage for SBx (Dorfinger et al., 2022). However, many studies differ in methodology, the definition of clinical importance, and the degree of blinding, which could affect results. There are also a few articles that examine the possibility of overdiagnosis and overtreatment in multi-modal biopsies (Lenfant et al., 2022).

Overall, using both TBx and SBx together increases sensitivity but also highlights the need for standardization. Further research is required to clarify the exact role of each method and to address current gaps in the evidence.

Practical implications

The role of systematic biopsy (SBx) remains debated in the era of widespread mpMRI use. Evidence suggests that SBx is most helpful in biopsy-naïve men (Elkhoury et al., 2019), in patients with PI-RADS 3 lesions, and in those who have a positive digital rectal examination or elevated PSA density. These findings are in line with current European recommendations, which advise performing both SBx and targeted biopsy during the initial diagnostic assessment.

This article review focuses on scientific articles evaluating MRI-TRUS fusion TBx against systematic biopsy. The role of the biopsy method on diagnostic accuracy is further described. TBx generally identifies a larger number of csPCa cases compared to SBx, irrespective of the population being analyzed (Lenfant et al., 2022). The combination of TBx and SBx increases the likelihood of diagnosis but requires more biopsy cores. In certain circumstances, this might lead to the detection of a disease that does not require intervention.

When clinicians use mpMRI-guided sampling, the probability of detecting significant PCa per patient remains equal regardless of whether we take the TR or TP route (Zattoni et al., 2024). The TP approach makes it easy to sample anterior or apical lesions (Uleri et al., 2023). Economic models generally support MRI-first strategies and targeted sampling because they reduce unnecessary biopsies and limit costly complications (Merriel et al., 2023). For regular clinical practice, it has been demonstrated that a TP done in an outpatient clinic environment with local anesthesia has an extremely low rate of infections and hence does not require antibiotic prophylaxis as a rule. On the other hand, TR procedures involve puncturing the needles through the rectum and increase the chances of developing sepsis to about 1% despite the use of prophylaxis (Hu et al., 2024). Studies using similar fusion devices have shown that the size and number of cores are greater in TP procedures, which may provide guidance on how best to manage treatment decisions for focal therapy patients (Kaneko et al., 2023). Overall, although both techniques can be used by doctors, TP is preferred over TR to avoid infections, antibiotics, or anterior lesions.

Complication rates are usually similar between the two techniques. Soreness of the perineum and sometimes urinary retention are possible complications of larger TP templates, while rectal bleeding is much more common after TR biopsy (Najjar et al., 2025). The possibility of performing TP biopsies under local anesthesia without much pain and with an extremely small risk of infection is an important benefit for many men. A lower infection rate reduces hospitalization frequency and associated healthcare costs.

Table 1. Detection rates of clinically significant prostate cancer across PI-RADS v2 score categories in the analyzed studies.

References	Patients (n)	PI-RADS 3 (%)	PI-RADS 4 (%)	PI-RADS 5 (%)
(Elkhoury et al., 2019)	248	23	64	80.2
(Diamand et al., 2019)	443	17.6	45.6	30.9
(Oderda et al., 2019)	1119	19	47	80
(Labra et al., 2020)	122	36.7	72.1	90.3

Based on 14 studies involving 9,507 patients, TBx and SBx showed similar overall detection rates. However, TBx was more often associated with the identification of clinically significant PCa and lower rate of indolent cancers than SBx (Lenfant et al., 2022). The use of all three types of procedures revealed that TBx+SBx provided the best detection rate of csPCa (Riskin-Jones et al., 2025; In de Braekt et al., 2024; Dorfinger et al., 2022; Exterkate et al., 2020; Borkowetz et al., 2018; Hakozaki et al., 2017; Puech et al., 2013). Such observations suggest that systematic cores can sample mpMRI-occult foci of a multifocal tumor. However, performance varied by risk level with mpMRI. This trend and the inherent variability between different cohorts are well illustrated in the appended table (Elkhoury et al., 2019; Diamand et al., 2019; Oderda et al., 2019; Labra et al., 2020), which demonstrates how cancer detection rates generally escalate with higher PI-RADS categories, yet show a significant range across studies, such as 17.6% to 36.7% for PI-RADS 3 and 45.6% to 72.1% for PI-RADS 4 lesions (Table 1). TBx outperformed SBx for PI-RADS 4–5 lesions (Mannaerts et al., 2019; Riskin-Jones et al., 2025; In de Braekt et al., 2024; Dorfinger et al., 2022; Borkowetz et al., 2018). As for the results obtained on PI-RADS 3 lesions, there was inconsistency, with an advantage of SBx noted in some studies (Dorfinger et al., 2022). It becomes apparent that there can be no universal one-size-fits-all strategy. Thus, in a clinical setting, TBx must be the core of the biopsy protocol for patients with visible

lesions on mpMRI. Additional SBx can be applied on an individual basis only, e.g., in cases with non-negligible pretest probability of MRI-invisible csPCa (e.g., biopsy-naïve men, PI-RADS 3, high PSA density, positive DRE, suboptimal MRI quality).

Linkage between the two kinds of data is clear. An approach that focuses on MRI results in a lower biopsy rate and less over-diagnosis. While the targeted methods, whether it is fusion, cognitive, or in-bore, are more expensive than the conventional transrectal ultrasound (TRUS) procedure, they come with lower costs overall due to fewer biopsies performed (Merriel et al., 2023; Wilson et al., 2021). Modeling for publicly funded health care reveals that TP initiatives can achieve cost-neutral status or even save money provided the equipment is relatively inexpensive.This occurs mainly because they avoid hospital admissions for sepsis (Callender et al., 2021; Venderink et al., 2017). In addition, such outcomes help the antimicrobial stewardship programs to limit the use of broad-spectrum antibiotic prophylaxis.

A patient-centred approach to developing evidence-based diagnostics is recommended. In particular, the first step in applying a diagnostic algorithm is performing an MRI scan (Merriel et al., 2023; Wilson et al., 2021). TBx should take place for MRI visible lesions, whereas SBx needs to be used selectively for biopsy naïve cases, PI-RADS 3 lesions, increased PSA density, positive digital rectal examination, and poor-quality MRI images (Lenfant et al., 2022; Riskin-Jones et al., 2025; In de Braekt et al., 2024; Dorfinger et al., 2022; Borkowetz et al., 2018). The use of TP access should be made to avoid infection, reduce the use of antibiotics, and collect samples from the lesions in the anterior and apical zones (Zattoni et al., 2024; Hu et al., 2024; Uleri et al., 2023). Previous experience and practice dictate the selection of these alternatives. The current evidence does not suggest that there is any notable difference among the above procedures when detecting clinically significant prostate cancer (Chang et al., 2021). Therefore, clinicians should make the decision considering local conditions.

There is considerable heterogeneity among the studies included in the current body of evidence. Differences are found in the MR imaging protocols used, the level of experience of the radiologists who read the results, and even the efficiency of the image fusion systems. There is also variation in the way csPCa was defined. These differences will impact the outcomes of the studies and make it difficult to formulate a recommendation for all possible scenarios (Lenfant et al., 2022; Riskin-Jones et al., 2025; In de Braekt et al., 2024; Dorfinger et al., 2022; Exterkate et al., 2020; Borkowetz et al., 2018; Hakozaki et al., 2017; Puech et al., 2013). Another point is that the number of biopsy cores taken and whether any systematic biopsy is performed simultaneously will increase heterogeneity.

4. CONCLUSION

In the era of MRI, fusion-biopsy makes the diagnosis of significant cancer more likely, but combining TBx and SBx yields maximum sensitivity, especially for biopsy-naive patients and PI-RADS 3 lesions. TB and SB have equal accuracy, but TB offers greater benefits in anterior and apical sampling, as well as infection prevention. While there is evidence to exclude SBx when higher-quality data exist, which justifies exclusion, selective risk-based integration of both techniques may be the way forward, particularly for TB when possible.

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Conceptualization: Piotr Banaszek, Mateusz Mazurek, Adam Szmidt
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Supervision: Piotr Banaszek

Informed consent

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Ethical approval

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Conflict of interest

The authors declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Data and materials availability

All data associated with this study will be available based on the reasonable request to corresponding author.

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