Importance of biopsy sample length for cancer diagnosis during trans-perineal prostate biopsy

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Abstract

Objective To identify the factors that determine the minimum length of biopsy sample required for accurate diagnosis.

Materials and methods A retrospective analysis was conducted on 1202 cases that underwent rectal ultrasound-guided trans-perineal prostate biopsy (TPB) with standardized biopsy surgical procedures and pathological evaluation. Logistic regression correlation analysis and the imbalance between groups was eliminated by propensity score matching of patients' own factors between groups (positive group and negative group). ROC curve optimal threshold analysis were performed to identify the independent factors associated with cancer detection rate and the minimum length of biopsy sample required for accurate diagnosis.

Results The study included 1202 cases that underwent standardized 8–18 needle initial puncture biopsies from June 2020 to October 2023. The cancer detection rate was 40.02% (481/1202), with Gleason scores of 6, 7, 8, 9, and 10 in 164, 134, 107, 67, and 9 patients, respectively. The percentage of patients with clinical significance (International Society of Urological Pathology (ISUP) ≥ 2) was 65.90% (317/481). Multivariate analysis showed that age,prostate-specific antigen(PSA), prostate volume,positive multi-parametric magnetic resonance imaging (mp-MRI) and length of biopsy samples were significant factors ($P < 0.05$)。 Interestingly, biopsy sample length did not correlate with the prostate volume (Pearson correlation $P = 0.069$). ROC curve analysis: The area under the curve AUC for sample length were 0.674 and 0.664 at before and after propensity score matching,respectively; the optimal thresholds were 12.25 mm and 11.00mm at before and after propensity score matching,respectively.

Conclusion The independent predictors of cancer detection rate during TPB are age, PSA, prostate volume, positive mp-MRI, and sample length. Among these, sample length is the most critical indicator affecting puncture quality, and the minimum value of biopsy sample length to be obtained is 11.00mm.

Keywords Prostate tumor, Trans-perineal biopsy, Diagnosis, Biopsy sample length, Propensity score matching

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Introduction

Prostate cancer is commonly diagnosed using prostate biopsy, which involves trans-rectal ultrasound guidance, and yields a cancer detection rate of 34.1–45% [1–3]. To enhance detection rates, supplementary approaches, including additional puncture needles [2, 3], multi-parametric magnetic resonance imaging (mp-MRI) [4, 5], or ultrasound fusion puncture, are often employed. Nonetheless, the mp-MRI and related fusion puncture

Zhu *et al. BMC Urology*   (2024) 24:209

Page 2 of 9

methods require specialized intelligent software, which may not yield the expected outcomes [5, 6]. Additionally, increasing the number of punctures inevitably increases the risk of injuries and complications [7, 8]. Prior research indicated that longer sampled tissues (biopsy sample length) and a larger volume of tissue samples for histopathological examination could improve cancer detection rates while utilizing the same number of puncture needles [9, 10]. Quantitative histologic examination useful to predict nonorgan-confined prostate cancer when saturation biopsy is performed [11]. However, there is limited research on the impact of biopsy core sample length on cancer detection rates [12, 13]. As far as we know, no studies have been reported on the relationship between specimen length and diagnostic rate in the TPB. To address the imbalance and confounding bias between the positive and negative groups, we employed the propensity score matching statistical method. This approach allowed us to analyze the impact of specimen length on diagnostic accuracy and to identify factors influencing the cancer detection rate. Additionally, we investigated the minimum biopsy sample length needed to enhance the quality of the biopsy and improve detection rates in TPB.

Materials and methods

TPB have been performed in our institution since 2003, and standardized TPB guided by rectal ultrasound and mp-MRI have been conducted since 2013 [14].We have been implementing standardization since 2017, with prospective records and data storage. This study analyzed all consecutive cases from June 2020 to 2023 October. The present study involved obtaining individual biopsy samples, which were then pathologically analyzed and documented, including their anatomical location within the prostate. The study protocol was approved by the Ethics Committee of Jinhua Hospital (ethics number: 2021-ethics-250). After obtaining informed consent from the patients, rectal ultrasound-guided TPB were performed, and samples were collected.

Biopsy criteria

The study cohort included subjects with abnormal findings during a digital rectal examination, prostate-specific antigen (PSA) levels exceeding 4 ng/ml, and suspicious prostate signals based on ultrasound and MRI [15].

Preoperative preparation

Patients who met the criteria for a trans-perineal prostate biopsy (TPB) underwent preoperative examinations, including blood tests and coagulation function assessments. Two days prior to the biopsy, patients were prescribed oral antibiotics. On the day of the procedure, a cleansing enema was administered, and the patient provided signed informed consent for the prostate biopsy.

Informed consent

Informed consent is critical to the success of any procedure, including TPB. Patients were thoroughly briefed about their ultrasound clinic visit during the outpatient consultation. They were given contact information for a prostate cancer specialist and nurse to address any questions. On the day of the biopsy, the ultrasound physician reviewed the procedure in detail, explaining the risks, benefits, and alternatives before obtaining informed consent.

Key points covered in the informed consent for TPB included the risks of postoperative sepsis, urinary tract infection, acute urinary retention, and the potential need for general anesthesia. Patients were also informed that hematuria or hemospermia is common after the procedure, typically resolving on its own. Hematuria may persist for over two weeks, and hemospermia can last for up to six weeks. Additionally, based on reports from over 3,000 patients, perineal pain is the most common postoperative symptom. Patients were advised that perineal pain or bruising is normal and can be managed with simple analgesics, such as Diclofenac enteric-coated tablets.

Biopsy equipment

All patients underwent preoperative mp-MRI (1.5/3.0 Philips MRI), and the images were reviewed prior to the biopsy. The biopsy was performed using a 25 cm 18-gauge Tru-Cut needle with an American Bard automatic biopsy gun. A rectal convex array probe and biplane probe with a probe frequency of 2–12 MHz from an Esaote My Lab 90 color ultrasound machine from Italy were used to obtain biopsy tissue in the sagittal plane. Real-time images from both mp-MRI and ultrasound were used during the procedure.

Biopsy method

Biopsy procedures [14]: The patient was positioned in the lithotomy position, and routine sterilization was performed. Local anesthesia was administered using 1% lidocaine, with general anesthesia used in 33 cases. A transrectal ultrasound-guided biopsy was conducted using an 18G disposable automatic biopsy device. Four needles were inserted into the bilateral peripheral zone—two into the external gland and two at the junction of the internal and external glands. Additionally, one needle was placed in the bilateral transitional zone, targeting the internal gland. Based on the patient's CT and MRI results, additional needles were used to target suspicious prostate nodules. The standard needle length was 1.5–1.7

Zhu *et al. BMC Urology*   (2024) 24:209

Page 3 of 9

cm. If the tissue sample was fragmented, 1–2 extra needles were inserted.

Firstly, prostate volume was calculated using the prostate ellipsoid formula (width × length × height × π /6). The first biopsy was divided into two ways depending on prostate size. As for prostate volume of < $50 cm^3$, 8 + X cores were taken as designated by a standardized biopsy scheme, including the lateral (two symmetrical needles respectively), the junctional region between the medial and lateral (one symmetrical needle respectively), the medial (one symmetrical needle respectively), and the suspected region, like the abnormal prostate nodule (X symmetrical needles). As for prostate volume of > 50 cm^3, 10 + X or 12 + X cores were taken. Based on 8 + X, the 10 + X scheme added two more symmetrical needles in the junctional region between the medial and lateral. Moreover, the 12 + X scheme added two more symmetrical needles in the apex, based on the scheme of 10 + X. During the second biopsy, saturation puncture was performed using 20 cores, including the lateral (three symmetrical needles respectively), the junctional region between the medial and lateral (three symmetrical needle respectively), the medial (two symmetrical needle respectively) and the apex (two symmetrical needle respectively).

Specimen sampling

A trained nurse was responsible for retrieving and visually assessing the biopsy samples. If a sample was deemed inadequate due to its size, fragmentation, or lack of tissue, an immediate repeat biopsy was performed at the same location. Each sample was carefully removed from the biopsy needle and placed on filter paper or moistened gauze for observation before being stored in a bottle containing formalin. When the core tissue filled the entire length of the needle groove, it was considered to meet quality standards, and the recorded sample length was the groove length. If the tissue was insufficient, short, or fragmented, it was considered suboptimal, and a repeat biopsy was conducted in the same anatomical area. The length of each needle was measured with a sterile disposable ruler and recorded. Each biopsy was stored separately in labeled bottles according to the prostate's anatomical location (e.g., right or left lateral, medial, junctional region between medial and lateral, apical region, and suspicious target area). If a second sample was obtained from the same site, it was stored in the same bottle as the initial suboptimal sample. Although we did not have a formal training and evaluation program for the participating surgeons, all procedures were either performed by or assisted by the same highly experienced physician (Zhou, with over 10 years of TPB experience). The sample quality was consistently assessed by the same specialist nurse, who promptly evaluated each sample upon removal from the needle.

Pathology report

The biopsy samples were evaluated by two experienced pathologists who measured and processed each needle biopsy sample independently. Hematoxylin and eosin (HE) staining was performed, followed by sectioning and microscopic observation. The length of each biopsy sample was measured in millimeters, and the percentage of cancerous tumor tissue per needle was calculated as the length of cancerous tumor tissue divided by the total length of the sample. In instances where more than one piece of tissue was obtained at the same site due to fragmentation or poor-quality re-puncture, the pathologist reported the length of each sample and the percentage of cancerous tumor tissue per piece as a marker. However, only samples with longer tissue lengths were analyzed, and smaller fragments were excluded.

Inclusion and exclusion criteria

The study included patients who had undergone a standardized initial biopsy procedure consisting of 8–18 punctures. Cases that did not meet the inclusion criteria were excluded, including those with fewer than 8 or more than 18 cores, those who underwent a repeated 20-cores saturation puncture biopsy, and those whose core samples lacked prostate tissue or contained only periprostatic tissue or blood. Patients with incomplete data or with pathology reports of atypical small alveolar hyperplasia or high-grade intraepithelial neoplasia classified as benign were excluded from the study.

Statistical analysis

We assessed the impact of specimen length on cancer detection following TPB. Initially, we collected and compared demographic and preoperative data between the positive and negative groups, analyzing over 10 variables, including age and body mass index. Next, we employed multiple logistic regression analysis to identify key factors influencing cancer diagnosis rates in patients who underwent TPB. Most covariates related to the effect of prostate biopsy on cancer detection were included [4, 5, 10–12, 16–18], while potential confounders were excluded using a propensity score matching approach. To evaluate the predictive power of specimen length on cancer diagnosis, we calculated the area under the receiver operating characteristic (ROC) curve using the trapezoidal rule. The optimal cut-off point (Maximum Youden index) was determined as the value with the highest sensitivity and specificity.

Statistical analysis and propensity score matching was performed using the SPSS 27.0 software package.The

Zhu *et al. BMC Urology*   (2024) 24:209

Page 4 of 9

measurement factors, including age, body mass index (BMI),PSA, PSA density (PSAD), free to total PSA ratio [PSA(f/t)], prostate volume, number of biopsy needles, and length of biopsy samples, were expressed as Mean ± SD. The categorical factors, such as digital rectal examination (presence of suspicious nodules), positive mp-MRI (Mp-MRI was performed, and prostate cancer was suspected (at least one suspicious lesion with PI-RADS score ≥ 3 [19]), crushed needle core (presence or absence), and pathological analysis (whether the cancer was confirmed), were expressed as frequency and percentage. Logistic regression was used to analyze factors associated with cancer detection. Pearson correlation analysis investigated the relationship between the two variables.

Multivariate Logistic regression models were used to propensity score matching the self-factors of patients in both groups (positive and negative), self-factors included age, BMI, abnormal digital rectal examination, PSA, PSAD, PSA (f/t), prostate volume, positive mp-MRI, number of biopsy cores and broken needle core. The propensity score matching ratio was 1:1, with a matching tolerance of 0.02.

Independent variables with statistical significance were subjected to receiver operating characteristic (ROC) curve analysis, and the area under the curve (AUC) was calculated. An AUC value greater than 0.5 was considered significant, and the optimal threshold value(the cut-off value) was determined using Youden's index. A *P*-value less than 0.05 was statistically significant.

Results

General data

A total of 1258 patients underwent an initial biopsy with 8–18 stitches. However, after cases with incomplete data ($n = 5$) and diagnosed with atypical small glandular follicular hyperplasia ($n = 51$) were excluded, 1202 cases were included. Of the 1202 patients, 59 (4.91%) with pathology showing high-grade prostatic intraepithelial neoplasia were classified as benign, while 481 (40.02%) were diagnosed with prostate cancer. Among those diagnosed with prostate cancer, 164, 134, 107, 67, and 9 patients had Gleason scores of 6, 7, 8, 9, and 10, respectively. 65.90%(317/481) had clinically significant cancer(csPCa) (International Society of Urological Pathology (ISUP) ≥ 2 [19, 20]). The mean number of cores per puncture was 10.69 ± 1.97, the mean sample length per needle was 13.3 ± 3.2 mm, and the broken needle core cases 384(31.95%) (Table 1).

Related factor analysis

Logistic regression correlation analysis showed that the cancer detection rate was significantly correlated with

Table 1 Characteristics of the study population ($n = 1202$)

Variables	Mean ± SD($\bar{x} \pm s$), or n (%)
Age (years)	68.99 ± 9.49
BMI (kg/m^2)	22.97 ± 2.97
Abnormal digital rectal examination (n, %)	
Yes	610(50.75)
No	592(49.25)
PSA (ng/ml)	22.79 ± 26.47
PSAD (ng/ml/cm^3)	0.63 ± 1.01
PSA (f/t,$\bar{x} \pm s$)	0.18 ± 0.22
Prostate volume (cm^3)	44.43 ± 21.01
Positive Mp-MRI (n, %)	
Yes	656(54.58)
No	546(45.42)
Number of biopsy cores (cores,$\bar{x} \pm s$)	10.69 ± 1.97
Sample length (mm)	13.3 ± 3.2
Broken needle core cases (n, %)	
Yes	384(31.95)
No	818(68.05)

BMI Body mass index, *PSA* Prostate-specific antigen, *PSAD* Prostate-specific antigen density, *PSA(f/t)* Free to total PSA ratio, *Mp-MRI* Multiparametric magnetic resonance imaging

age, Abnormal digital rectal examination, PSA, PSAD, prostate volume, mp-MRI and sample length ($P < 0.05$) based on univariate analysis results. In contrast, only age, PSA, prostate volume, mp-MRI,and sample length were significantly correlated ($P < 0.001$) based on multivariate analysis results (Table 2). Additional analysis using Pearson correlation showed that the length of the biopsy sample did not have a significant correlation with the age ($P = 0.168$), PSA ($P = 0.148$)and the volume of the prostate ($P = 0.069$).

Propensity score matching

Among the five independent factors, the first four factors are all patients own factors, the sample length was a key technical factor in determining the quality of the puncture. Therefore, we performed propensity score matching on self-factors to reduce the imbalance between the positive and negative groups, and further explored the effect of specimen length on diagnostic accuracy.

One thousand and two patients (481 in the positive group and 721 in the negative group) were Propensity score matching for their own factors, self-factors included age, BMI, abnormal digital rectal examination, PSA, PSAD, PSA (f/T), prostate volume, positive mp-MRI, number of biopsy cores and broken needle core. A total of 602 cases (301 positive and 301 negative cases respectively) were successfully matched. After matching, the self-factors of the two groups had no statistical

Zhu *et al. BMC Urology* (2024) 24:209

Page 5 of 9

Table 2 Analysis of factors associated with logistic regression of cancer detection rate

Variables[$\bar{x}\pm s$, or n (%)]	univariate analysis		multivariate analysis	
	OR(95%CI)	*p* value	OR(95%CI)	*p* value
Age (years)	1.054(1.040–1.068)	<0.001	1.044(1.027–1.061)	<0.001
BMI (kg/m^2)	0.967(0.930–1.006)	0.097		
abnormal digital rectal examination (n, %)	0.244(0.191–0.313)	<0.001	1.180(0.565–2.465)	0.660
PSA (ng/ml)	1.036(1.030–1.042)	<0.001	1.019(1.002–1.036)	0.028
PSAD (ng/ml/cm^3)	4.593(3.546–5.950)	<0.001	1.501(0.774–2.913)	0.230
PSA (f/t, $\bar{x}\pm s$)	1.012(0.595–1.722)	0.964		
Prostate volume (cm^3)	0.983(0.976–0.989)	<0.001	0.981(0.971–0.991)	<0.001
Positive Mp-MRI(n,%)	0.230(0.178–0.297)	<0.001	0.269(0.128–0.565)	<0.001
Number of biopsy cores (cores, $\bar{x}\pm s$)	1.038(0.979–1.101)	0.210		
Broken needle core cases (n, %)	1.206(0.940–1.548)	0.141		
Sample length (mm)	67.370(30.204–150.271)	<0.001	64.330(26.068–158.751)	<0.001

BMI Body mass index, *PSA* Prostate-specific antigen, *PSAD* Prostate-specific antigen density, *PSA(f/t)* Free to total PSA ratio, *Mp-MRI* Multiparametric magnetic resonance imaging

significance ($p > 0.05$). The Sample length was 14.8 ± 0.9 mm and 12.4 ± 3.6 mm, respectively, which was still statistically significant ($p < 0.001$) (Table 3).

ROC curve analysis

The area under the curve AUC for age, PSA, positive mp-MRI, prostate volume and sample length were 0.629 (95%CI:0.597–0.661), 0.717 (95%CI:0.687–0.747), 0.671 (95% CI:0.640–0.702), 0.617 (95% CI:0.584–0.649) (Since prostate is a negative indicator, the smaller the volume, the higher the diagnostic rate, so it was converted in a positive direction) and 0.674 (95%CI:0.645–0.704), respectively (Fig. 1).

The area under the curve AUC for sample length were0.674 (95%CI:0.645–0.704) (Fig. 2A) and 0.664 (95%CI:0.620–0.707) (Fig. 2B) at before and after propensity score matching,respectively. The optimal thresholds for sample length were 12.25 mm (sensitivity 96.0% and specificity 63.5%) (Fig. 2A) and 11.00mm (sensitivity 98.3% and specificity 67.4%) (Fig. 2B) at before and after propensity score matching,respectively (Fig. 2).

Discussion

Prostate cancer is a prevalent male malignancy and ranks second among the leading causes of death in men [21]. The standard for diagnosis is the transrectal ultrasound-guided prostate biopsy, which has a diagnostic rate of 34.1–45% [1–3]. Although global clinical recommendations have extensively embraced the MRI-guided fusion biopsy technique, its implementation is intricate and

Table 3 Characteristics of the two groups before and after propensity score matching

Variables[$\bar{x}\pm s$, or n (%)]	Before propensity score matching			After propensity score matching		
	Positive($n = 481$)	Negative($n = 721$)	*p* value	Positive($n = 301$)	Negative($n = 301$)	*p* value
Age (years)	71.62 ± 8.54	67.23 ± 9.69	<0.001	69.02 ± 8.13	69.76 ± 8.98	0.289
BMI (kg/m^2)	22.08 ± 2.86	23.09 ± 3.04	0.097	22.95 ± 2.96	22.91 ± 2.97	0.874
Abnormal digital rectal examination (n, %)	341(70.9)	140(37.3)	<0.001	172(57.1)	172(57.1)	0.869
PSA (ng/ml)	35.20 ± 33.15	14.51 ± 16.25	<0.001	19.51 ± 20.17	19.94 ± 22.13	0.804
PSAD (ng/ml/cm^3)	1.05 ± 1.41	0.36 ± 0.45	<0.001	0.52 ± 0.47	0.52 ± 0.61	0.935
PSA (f/t, $\bar{x}\pm s$)	0.18 ± 0.31	0.18 ± 0.11	0.964	0.18 ± 0.32	0.18 ± 0.12	0.817
Prostate volume (cm^3)	40.29 ± 19.72	47.20 ± 21.40	<0.001	41.33 ± 21.26	43.32 ± 19.61	0.233
Positive Mp-MRI(n,%)	361(75.1)	120(40.9)	<0.001	188(62.5)	188(62.5)	0.558
Number of biopsy cores (cores, $\bar{x}\pm s$)	10.78 ± 1.93	10.64 ± 1.99	0.210	10.66 ± 1.71	10.86 ± 1.86	0.178
Broken needle core cases (n, %)	142(29.5)	242(33.6)	0.141	88(29.2)	88(29.2)	0.594
Sample length (mm)	14.8 ± 1.2	12.3 ± 3.7	<0.001	14.8 ± 0.9	12.4 ± 3.6	<0.001

BMI Body mass index, *PSA* Prostate-specific antigen, *PSAD* Prostate-specific antigen density, *PSA(f/t)* Free to total PSA ratio, *Mp-MRI* Multiparametric magnetic resonance imaging

Zhu *et al. BMC Urology*   (2024) 24:209

Page 6 of 9
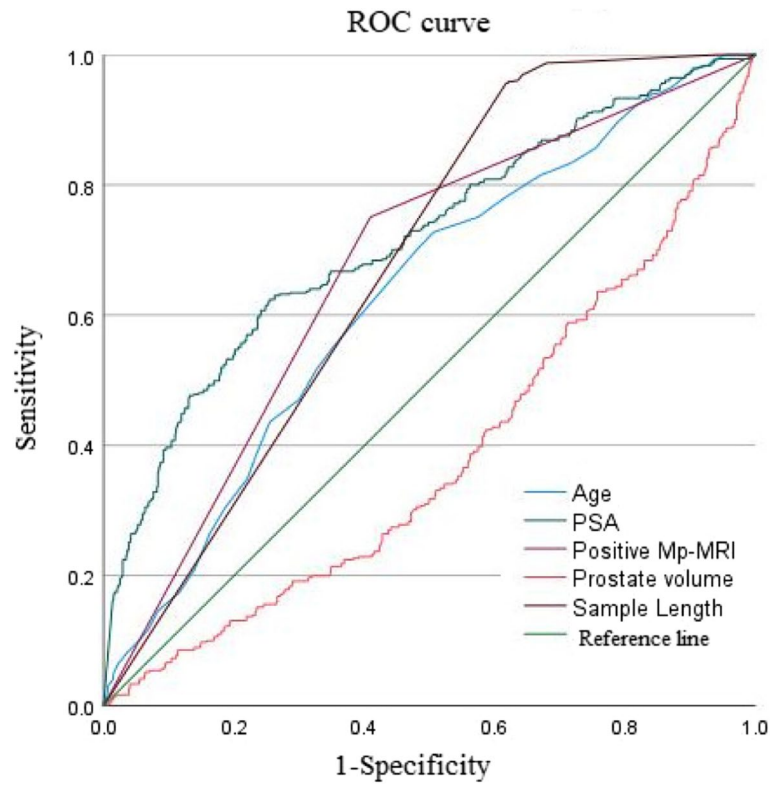
Fig. 1 ROC curve analysis. The area under the curve AUC for age, PSA, mp-MRI, prostate volume and sample length were 0.629,0.717,0.671,0.617 (Since prostate is a negative indicator, the smaller the volume, the higher the diagnostic rate, so it was converted in a positive direction) and 0.674, respectively

(A) Before propensity score matching

(B) After propensity score matching
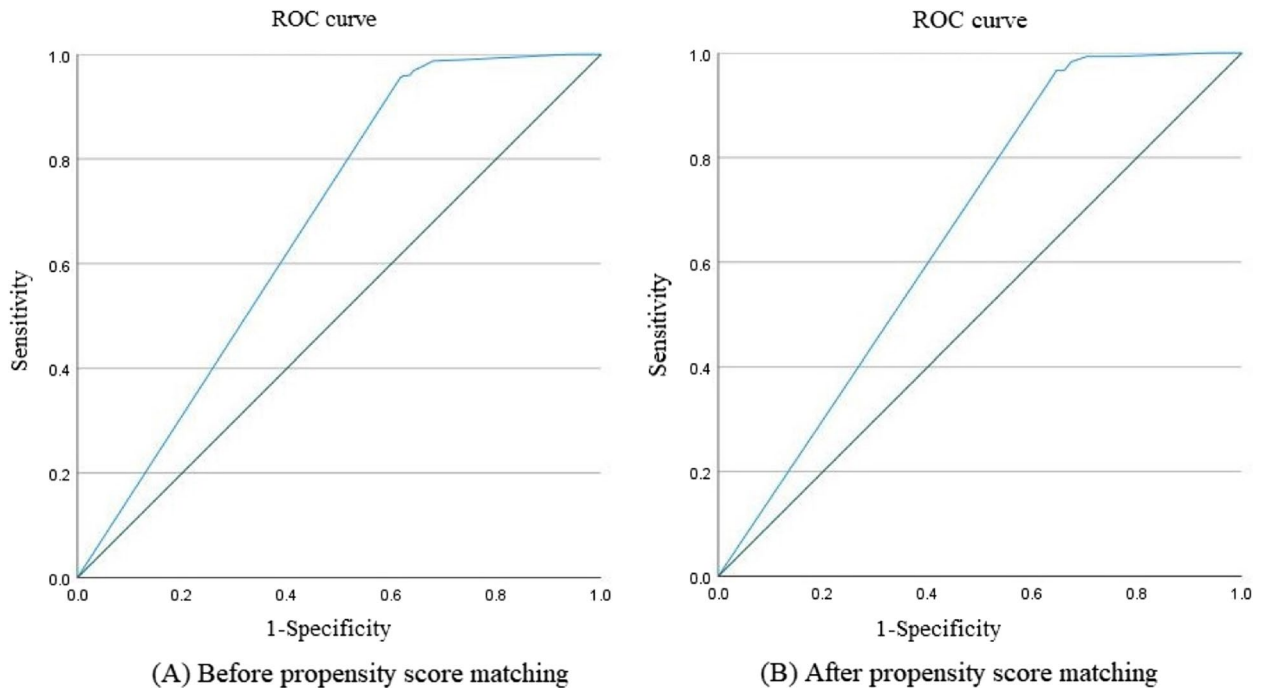
Fig. 2 The area under the curve AUC for sample length were0.674 (**A**) and 0.664 (**B**) at before and after propensity score matching, respectively; the optimal thresholds for sample length were 12.25 mm (**A**) and 11.00mm (**B**) at before and after propensity score matching, respectively

Zhu *et al. BMC Urology*   (2024) 24:209

Page 7 of 9

necessitates specific software [4, 5].Pepe et al. recently performed a prospective evaluation of 68GA-PSMA PET/CT in 160 patients and concluded that 68GaPSMA PET/CT with a SUVmax cut-off of 8 demonstrated a good accuracy in the diagnosis of csPCa [22]. A prospective evaluation of needle core counts in 875 patients with perineal saturated biopsies found that: In men subject to mpMRI and/or perineal saturated biopsies, a maximum of 20 systematic transperineal needle cores detected all cases of csPCa and minimized the diagnosis of indolent cancers [23]. Increasing the number of biopsy needles to obtain samples from more sites increases the risk of injury and complications [5–7]. An alternative way to increase the tissue sampled for pathological examination with the same number of puncture needles is to obtain longer sampled tissue [8–10]. Several techniques have been developed to obtain longer biopsy samples for better pathological examination to address this [17, 18, 24, 25]. However, the impact of prostate biopsy sample length on cancer detection rates has not been thoroughly investigated [10, 12, 13, 24, 25], and attention to puncture quality has been inadequate [26]. Patients with low to intermediate-risk prostate cancer (ISUP < 2) often undergo active surveillance as a recognized approach [27–29], and the results of biopsies during this period are crucial in deciding whether to switch to active treatment methods like surgery. Our study highlights the significance of the quality of biopsies, as we found that cancer detection rates were highly linked with age, PSA, prostate volume, mp-MRI and sample length.At the same time, Our study found that sample length was still the key factor affecting the positive diagnosis rate after dispelling its own influence factor by propensity score matching.

It is now understood that various factors can influence the length of biopsy samples, including the biopsy physician, the puncture needle used, the sample acquisition method, the methods used for tissue processing, and pathological analysis [1, 3, 8–10, 26]. As documented in the literature, there is a marked inconsistency in sample length, with more than 3.6 times the variation in single-needle biopsy samples obtained via sextant site biopsy sampling [30]. However, biopsy needles with end-cutting features can be employed to obtain longer samples [26]. Furthermore, the transrectal versus perineal approach may affect the length of the samples obtained [31, 32]. In the present study, we minimized potential bias by implementing several measures during the biopsy, such as using the same physician, equipment, and biopsy needle via the trans-perineal route, having a nurse assess sample quality immediately after specimen removal, processing samples in a standardized manner, and limiting the number of needle cores. Our study revealed that although clinicians may opt for larger prostates to obtain longer

biopsy samples, sample length was unaffected by prostate volume, consistent with the findings of Iczkowski et al. [30].

Minimum biopsy sample length values have been reported to be associated with lower cancer detection rates due to insufficient prostate glandular tissue obtained during the biopsy. Therefore, a cut-off length of 6 mm is recommended [33]. Longer biopsy core sample lengths are associated with improved overall cancer detection rates, with a suggested cut-off core length of 11.8–12.0 mm [34–36]. Longer biopsy sample lengths also predict higher cancer volume and pathological staging in radical prostatectomy [37].Biopsy core length is one of the most important parameter that determines the quality of biopsy and detection of prostate cance [36]. All of these studies were performed with trans-rectal biopsies to determine the relationship between core length and cancer detection. Because the core length specimens obtained by this technique are mainly located in the peripheral zone of the prostate, the detection of cancers in the transitional and central zone (or ventral and apical regions of the prostate) and the detection of csPCa are inevitably affected.However, the TPB can be more comprehensive, accurate and easy to puncture the prostate anatomical region and hardly affect the detection of cancers in different regions. The detection rate of csPCa was 65.90%. Our research group conducted a study to determine the highest sensitivity and specificity by ROC analysis and found that the optimal threshold for biopsy sample length was from 12.25 mm before matching to 11.0 mm after matching. Additionally, we found that the AUC for biopsy sample length was from 0.674 before matching to 0.664 after matching,and increased sensitivity and specificity for cancer detection rate.It is indicated that the self-factors of the patients in both groups will have a significant influence on the optimal threshold for biopsy sample length. This finding may help explain the differences in cancer detection rates observed across different studies. Accordingly, biopsy sample length is a critical factor reflecting the quality of the puncture, it is a very important factor affecting the positive rate of diagnosis.

Limitations of this study

This study has several limitations. First, its retrospective design prevented us from assessing all potential covariates that might have influenced the analysis, which could introduce selection bias. However, we included nearly all relevant covariates associated with the impact of TPB on cancer detection rates and conducted a propensity score matching analysis to minimize bias. Second, the single-center nature of the study limits the generalizability of our findings. However, our data were

Zhu *et al. BMC Urology*   (2024) 24:209

Page 8 of 9

systematically collected and maintained electronically, ensuring the continuous and prospective capture of patient characteristics, oncologic outcomes, and complications. All patients were observed and rehabilitated in a daytime surgical ward, with detailed surgical records maintained. These results provide valuable clinical insights for real-world practice and contribute to the evidence base for future randomized clinical trials. They also facilitate comparisons between TPB and the current standard of transrectal biopsy. Third, since all TPB procedures were performed by highly specialized physicians and nurses at a single large medical center, the technique may not be easily transferable to other hospitals or facilities. Specialized training is required for its effective implementation. Finally, performing the procedure in an outpatient setting under local anesthesia may have caused some patients to experience pain, psychological stress, embarrassment, and discomfort, potentially affecting the accuracy of the biopsy and the number of needles used. Although the criteria applied in this study are widely used internationally [7, 10, 31], this could still introduce some bias to the final results.

Conclusion

Accurate diagnosis of prostate cancer relies on identifying independent factors that impact cancer detection rates during TPB, including age, PSA, prostate volume,positive mp-MRI, and sample length. Our study indicates that to ensure optimal puncture quality and maximize the sensitivity and specificity of cancer detection, a minimum biopsy sample length of 11.00 mm is required. Therefore, it is recommended that clinicians obtain biopsy samples of adequate length to achieve optimal diagnostic accuracy.

Declarations

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Zhu *et al. BMC Urology*   (2024) 24:209

Page 9 of 9

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