Zhang Z et al. (2024) TARGETED PROSTATE BIOPSY USING COGNITIVE FUSION IMAGING: ENHANCING DIAGNOSTIC PRECISION AND MINIMIZING COMPLICATIONS WITH IMPLICATIONS FOR PHYSICAL REHABILITATION IN PRIMARY CARE SETTINGS. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 24 (98.1) pp. 321-335.
DOI: https://doi.org/10.15366/rimcafd2024.98.1.022

ORIGINAL

TARGETED PROSTATE BIOPSY USING COGNITIVE FUSION IMAGING: ENHANCING DIAGNOSTIC PRECISION AND MINIMIZING COMPLICATIONS WITH IMPLICATIONS FOR PHYSICAL REHABILITATION IN PRIMARY CARE SETTINGS

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Recibido 22 de abril de 2024 **Received** April 22, 2024
Aceptado 16 de diciembre de 2024 **Accepted** December 16, 2024

ABSTRACT

Objective: To evaluate the application of targeted prostate biopsy using cognitive fusion imaging in primary hospitals, focusing on its impact on the accuracy of pathological examinations, complication rates, and implications for physical recovery and rehabilitation. **Methods:** A retrospective analysis was conducted on 200 patients who underwent prostate biopsy at primary hospitals between 2020 and 2023. Patients were divided into two groups: targeted biopsy using cognitive fusion imaging (n=100) and conventional systematic biopsy (n=100). Diagnostic accuracy, rates of clinically significant prostate cancer (CSPC) detection, complication rates (e.g., hematuria, infection, and urinary retention), and post-procedure recovery metrics, including time to resume physical activity, were analyzed and compared. **Results:** The cognitive fusion imaging group demonstrated significantly higher accuracy in detecting CSPC compared to the conventional biopsy group (84% vs. 68%, $P < 0.01$). Targeted biopsy reduced the number of cores required, minimizing tissue sampling and procedural invasiveness. Complication rates, including hematuria and infection, were significantly lower in the cognitive fusion imaging group ($P < 0.05$). Patients in the cognitive fusion imaging group resumed physical activity sooner, with a shorter mean recovery time compared to those undergoing conventional

biopsy (P < 0.01). **Conclusion:** Targeted prostate biopsy using cognitive fusion imaging significantly enhances diagnostic accuracy while reducing complication rates and improving recovery time. These findings highlight its potential as a superior diagnostic approach in primary hospitals, with added benefits for patient physical recovery and rehabilitation. The integration of advanced imaging technologies in routine care can improve patient outcomes and support faster resumption of physical activity. Further studies are recommended to explore long-term functional outcomes and the broader impact of cognitive fusion imaging on patient quality of life and rehabilitation.

KEYWORDS: Cognitive Fusion Imaging; Targeted Puncture Biopsy; Pca; Pathological Examination; Accuracy; Complications

1. INTRODUCTION

Prostate cancer is one of the leading causes of cancer-related morbidity and mortality among men worldwide (Boesen, 2019; Celma et al., 2019). Early detection and accurate diagnosis are crucial for initiating timely and appropriate treatment, significantly improving patient outcomes and survival rates. Prostate biopsy remains the gold standard for diagnosing prostate cancer; however, conventional systematic biopsy techniques have inherent limitations (Chung & Park, 2022; Elkhoury et al., 2019). These include a high risk of false-negative results, overdiagnosis of clinically insignificant cancers, and a considerable rate of procedure-related complications such as hematuria, infection, and urinary retention. These challenges underscore the pressing need for more precise and efficient diagnostic techniques (Lawal et al., 2020; Novaes et al., 2020), especially in primary care settings where advanced diagnostic tools and resources may be limited. Targeted prostate biopsy using cognitive fusion imaging is a promising innovation aimed at overcoming the limitations of conventional biopsy methods. By integrating multiparametric magnetic resonance imaging (mpMRI) and transrectal ultrasound (TRUS), cognitive fusion imaging enables more precise localization and sampling of suspicious lesions within the prostate (Numan et al., 2022; Rai et al., 2021; Sekhoacha et al., 2022). Unlike automated MRI-TRUS fusion systems, which may not be readily accessible in primary care hospitals, cognitive fusion relies on the operator's manual alignment of mpMRI data with real-time ultrasound images. This makes it a cost-effective and practical option for improving diagnostic accuracy in resource-constrained environments while maintaining high standards of care (Sivaraman et al., 2022; Uhr et al., 2020; Vietri et al., 2021). The adoption of targeted biopsy techniques has implications that extend beyond diagnostic accuracy. One of the significant advantages of cognitive fusion imaging is the reduction in the number of cores required for biopsy, thereby minimizing tissue sampling and procedural invasiveness. This not only reduces the risk of complications such as bleeding and infection but also shortens recovery times, allowing patients to resume their daily activities more

quickly. For many patients, particularly those with active lifestyles or those undergoing rehabilitation for other conditions, faster recovery and lower complication rates are essential for maintaining physical and functional health. Furthermore, targeted biopsy using cognitive fusion imaging aligns with the broader goals of modern medicine, which emphasize patient-centered care and the integration of advanced technologies into routine clinical practice. In primary hospitals, where resources and expertise may vary, the implementation of this technique represents a significant step toward bridging the gap between cutting-edge diagnostics and real-world accessibility. By improving diagnostic precision, reducing adverse events, and supporting faster recovery, cognitive fusion imaging has the potential to set new standards for prostate cancer diagnosis in these settings. This study aims to evaluate the application of targeted prostate biopsy using cognitive fusion imaging in primary hospitals. Specifically, it examines its impact on the accuracy of pathological examinations, the prevalence of procedure-related complications, and patient recovery metrics, including the time required to resume physical activity. By highlighting the advantages of this technique, the study seeks to provide a comprehensive understanding of its clinical value and practical implementation. Additionally, the findings will emphasize the role of cognitive fusion imaging in enhancing physical recovery and rehabilitation, underscoring its relevance to improving patient outcomes and quality of life in diverse healthcare settings. This research bridges the gap between advanced diagnostic methodologies and their application in everyday practice, ultimately contributing to better healthcare delivery and patient care in the context of prostate cancer (Cicero et al., 2019), and the incidence of PCa is also rising continuously in China (Haffner et al., 2021; Taguchi et al., 2021).

2. Patients and Methods

2.1 General Information

During July 2020 to December 2021, the clinical data of 131 patients with suspected PCa cured in our hospital were analyzed retrospectively. Ten routine systematic puncture biopsies and cognitive fusion imaging targeted puncture biopsies were performed. The pathological grades were classified into low, moderate and high-risk grades in accordance with Gleason score. The age of the patients was 35 to 71 years old (mean=48.28 ±8.19). The body mass index (BMI) was from 17.83 to 37.12kg/m^2 (mean=25.82±11.04). The volume of prostate ranged from 56.34 to 85.02mL (mean=70.38±13.94). There were 30 cases with family history of malignant tumor and 101 cases without family history of malignant tumor. All patients signed informed consent forms, which were approved by the Medical Ethics Association at our hospital.

Inclusion criteria: (1) According to the relevant criteria in reference (Sathianathen et al., 2018), the patient was diagnosed to perform the prostate

puncture; (2) no previous history of prostate puncture; (3) the total prostate specific antigen (tPSA) was 4 ~ 50 ng/ml; (4) abnormal lesions were found by mpMRI within one week before operation, and the score of Prostate Imaging Reporting and Data System (PI-RADS) was ≥ 3; (5) the medical records were complete.

Exclusion criteria: (1) more than 2 punctures; (2) acute prostatitis, indwelling catheter, etc. lead to abnormal PSA; (3) digital rectal examination or imaging examination indicated that the tumor invaded the capsule; (4) those who could not be examined by MRI; (5) patients had serious basic diseases and cannot tolerate anesthesia or puncture (such as severe pulmonary insufficiency, cardiovascular and cerebrovascular diseases, coagulation dysfunction, etc.); (6) patients were complicated with serious mental illness, cognitive dysfunction and unable to communicate with others normally. Sample size calculation formula:

$$n_1 = \frac{[Z_{\alpha/2}\sqrt{p(1-p)(1+c)/c} + Z_{\beta}\sqrt{p_1(1-p_1)+p_2(1-p_2)/c}]^2}{(p_1-p_2)^2}$$

The bilateral α is taken as 0.05 and β as 0.2, the detection rate of PCa is taken as the effect index, and the parameters are set as P1=0.95, P2=0.75. After calculation, the total sample size should be 119 cases, and 131 patients should be included in the calculation based on the shedding rate of 10%.

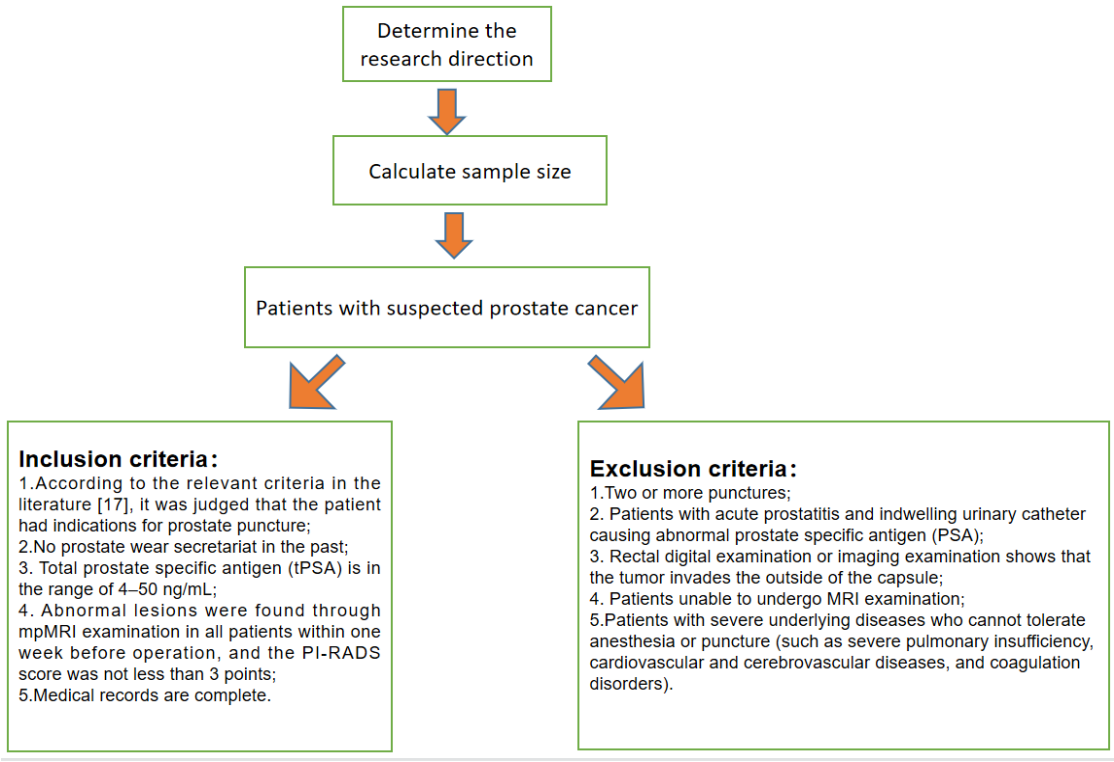

Figure 1: Schematic diagram of filtering into groups

2.2 Treatment Methods

The main results are as follows:

(1) The plan of cognitive fusion puncture:

a. Systematic puncture: prostate nuclear magnetic resonance examination was performed before operation, and the puncture site was marked 1-10 based on 10-needle systematic puncture.

b. Targeted puncture part: according to the MRI image and the system puncture 10 parts of cognitive fusion to determine the suspected targeted puncture site and the corresponding number (later this kind of number was collectively referred to as X).

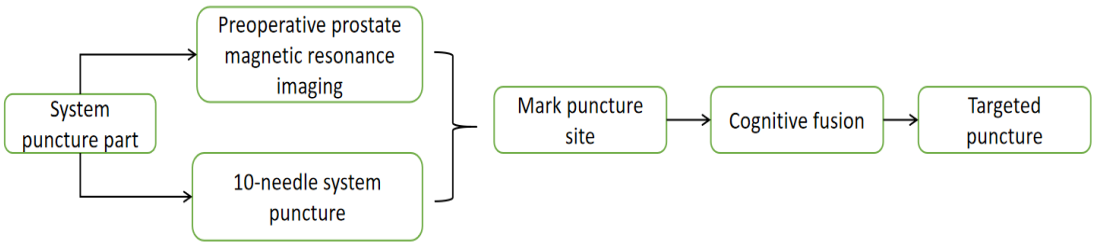

Figure 2: Schematic diagram of puncture plan

(2) Patients should stop taking anticoagulant or antiplatelet drugs such as aspirin for 7 to 10 days before operation.

(3) The patients were treated with enema before puncture, the skin was prepared in the puncture area, and the catheter was routinely indwelled.

(4) The patient was placed in stone position, the scrotum was fixed, the perineum was exposed, a coaxial puncture site was selected 1cm near the midline of the perineum, marked with a marker, the skin of the perineum was disinfected and a towel was laid.

(5) Lidocaine was extracted with 5ml syringe. The needle was inserted vertically at the marked point, and lidocaine was injected under the prostate capsule under ultrasonic observation.

(6) Perineal prostate biopsy was carried out under local anesthesia, and the ultrasonic probe implanted into the anus reached the designated site to observe the shape and size of the prostate. According to the puncture plan, the perineal coaxial prostate needle was punctured through the perineal coaxial prostate system, and the obtained samples were placed in serial specimen bottles and fixed with formalin and sent to the department of pathology for examination.

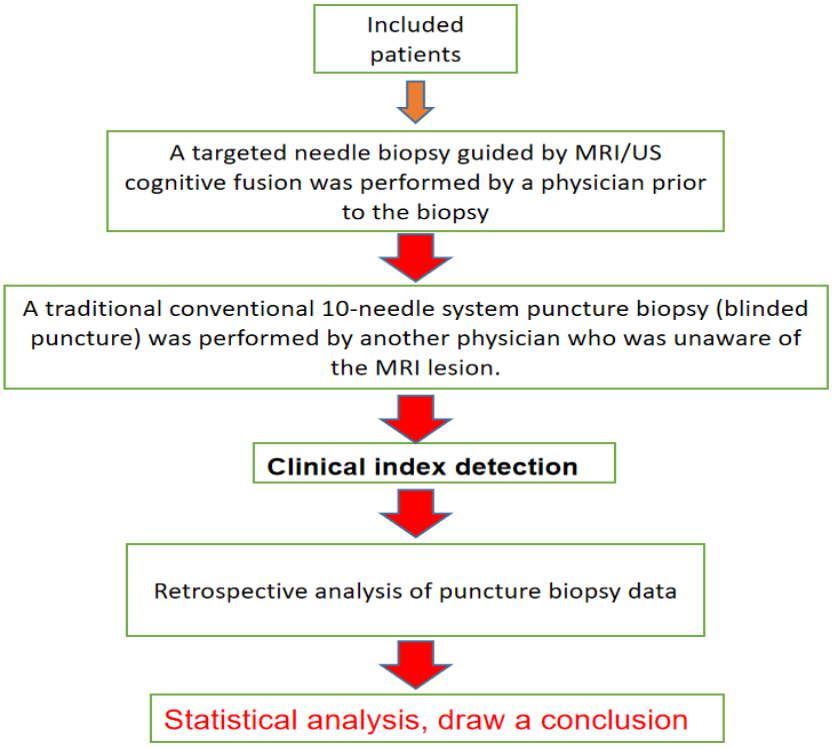

Figure 3: Research Technology Roadmap

2.3 Observation index

1. A comparison was made between the two methods of puncturing to determine whether PCa could be detected. The detection rate of PCa = (low risk cases + medium risk cases + high risk cases)/total number of cases × 100%.

2. The pathological risk grades of PCa detected by the two puncture methods were compared. Pathological analysis all biopsy specimens were pathologically diagnosed by two pathologists, including the Gleason score of primary and secondary differentiation (Taguchi et al., 2021). Low-risk biopsy is referred to as Gleason 6 or Gleason 3+4 for small volume fusion. Less than 50% of any needle sample contained cancer and less than 33% of the number of systemic biopsy needles were positive for cancer cells. Medium risk is defined as Gleason score of 3+4 (that is, any needle specimen contains cancer more than 50% or the number of cancer-positive needles in standard biopsy needles is more than 33%). The Gleason score of 4+3 or above is considered high-risk cancer.

3. The tPSA grading of the detection rate of PCa was compared between the two puncture methods (4ng / ml, 10ng / ml, and 20~50ng/mL).

4. The Gleason scores of PCa were detected by the two puncture methods were compared (6 points, 7 points, and ≥ 8 points).

5. In a comparison of the two puncture methods, a single needle

indicated a higher positive rate. The positive rate of single needle referred to the detection of PCa in a single puncture, and the positive rate of single needle meant the number of cases / total cases × 100% of PCa detected by one puncture.

6. The complication rates of the two puncture methods were compared. The cases of complications such as hematochezia, fever (body temperature > 38 ℃), vagus nerve reflex and urinary retention were counted between the two groups. Hematochezia means blood mixed in the excrement or blood before and after stool. Fever refers to an increase in body temperature, which in this article means an increase in body temperature >38°C. The vagal reflex also has a strong influence on pressure changes in the main venous arch. When the pressure in this area increases, it can cause vagal excitation and produce a hypotensive effect. Urinary retention refers to a disturbance in the excretion of urine, which is retained in the bladder.

2.4 Statistical Analysis

The data were analyzed and processed by SPSS22.0 statistical software. A ($\bar{x}$±s) symbol is used to indicate measurements with a normal distribution or approximate normal distribution. Comparing the two groups was done using paired t-tests, while comparing the two groups separately using independent sample t-tests. The n (%) was adopted to represent the counting data, and χ 2 test was adopted. P<0.05 was the differences were statistically remarkable.

3. Results

3.1 The Detection Rate of PCa by Two Puncture Methods

A total of 59 cases (45.04%) of PCa were found in 131 patients. PCa was found in 55 cases (41.98%) by targeted puncture and 54 cases (41.22%) by systematic puncture. In terms of PCa detection rates, the two methods indicated no significant differences (P>0.05, Table 1).

Table 1: The detection rate of PCa by two puncture methods

TARGETED PUNCTURE	**SYSTEMATIC PUNCTURE**				
	No Cancer was Detected	Low Risk	Medium and Dangerous	High Risk	Total
NO CANCER WAS DETECTED	66	9	1	0	76
LOW RISK	4	5	1	3	13
MEDIUM AND DANGEROUS	0	4	5	0	9
HIGH RISK	7	8	5	13	33
TOTAL	77	26	12	16	131

3.2 The Pathological Risk Grade of Pca Detected by Targeted Biopsy and Systematic Biopsy

Targeted biopsy detected more patients with high-risk prostate cancer compared to systematic biopsy, while fewer patients with low-risk prostate cancer were identified (P<0.05). Targeted puncture biopsy and systematic puncture biopsy did not remarkably differ in detecting PCa in medium-risk patients (P>0.05). In Table 2, you can see all the results.

Table 2: The pathological risk grades of PCa detected by targeted biopsy and systematic biopsy (n/%)

PATHOLOGICAL RISK GRADE	TARGETED PUNCTURE	SYSTEMATIC PUNCTURE	X^2	P
LOW RISK	13（0.010）	26（19.85）	5.091	＜0.05
MEDIUM AND DANGEROUS	9（6.87）	12（9.16）	0.467	＞0.05
HIGH RISK	33（25.19）	16（12.21）	7.255	＜0.05
TOTAL	55（41.98）	54（41.22）	0.016	＞0.05

3.3 The tPSA Score for the Detection Rate of Pca by Two Puncture Methods

According to tPSA, 131 patients were classified into three groups for stratified analysis. Among them, there were 50 cases with TPSA 4 ng/ml, 10 ng/ml ~ 52 cases and 29 cases with 20-50 ng/ml. PCa was found in 19 cases, 24 cases and 16 cases respectively. The positive puncture rate between the two methods was not remarkably different in different layers of tPSA (P>0.05, Table 3).

Table 3: The tPSA score for the detection rate of PCa by two puncture methods (n/%)

GROUP		TARGETED PUNCTURE (N=55)	SYSTEMATIC PUNCTURE (N=54)	X^2	*P*
TPSA	4ng/mL～	18（32.73）	17（31.48）	0.240	＞0.05
	10ng/mL～	22（40.00）	20（37.04）		
	20～50ng/mL	15（27.27）	17（31.48）		

3.4 Stratified Analysis of Gleason Score for the Detection Rate of Pca by Two Puncture Methods

According to Gleason score, 131 patients were classified into three groups for stratification analysis. The results indicated that there was no remarkable difference in the positive rate of puncture between the two methods among different Gleason scores (P>0.05, Table 4).

Table 4: The tPSA score for the detection rate of PCa by two puncture methods (n/%)

GROUP		TARGETED PUNCTURE（N=55）	SYSTEMATIC PUNCTURE（N=54）	X^2	*P*
GLEASON SCORING	6 points	3（5.45）	6（11.11）	1.151	＞0.05
	7 points	25（45.45）	23（42.59）		
	≥8 points	27（49.09）	25（46.30）		

3.5 Positive Rate of Single Needle

In this study, a total of 1310 systematic punctures were performed, out of which 184 were positive, resulting in a positive rate of 14.06% for a single needle. Among these, 94 were positive, yielding a positive rate of 34.40% for a single needle (P<0.05, Table 5).

Table 5: The single needle positive rate of two puncture methods

GROUP	NUMBER OF PUNCTURE NEEDLE	POSITIVE NUMBER	X^2	*P*
SYSTEMATIC PUNCTURE	1310	184	64.284	＜0.05
TARGETED PUNCTURE	274	94		

3.6 The Incidence of Complications Between Two Puncture Methods

After targeted puncture, hematochezia occurred in 1 case, body temperature > 38 ℃ in 1 case, vagus nerve reflex in 1 case during or after puncture. The total incidence of complications was 2.30% in the targeted puncture group. After systematic puncture, 4 patients had hematochezia, body temperature > 38 ℃ in 3 cases, urinary retention in 2 cases and vagus nerve reflex in 2 cases. The incidence of complications was 8.40% in the systematic puncture group (P<0.05, Fig. 4).

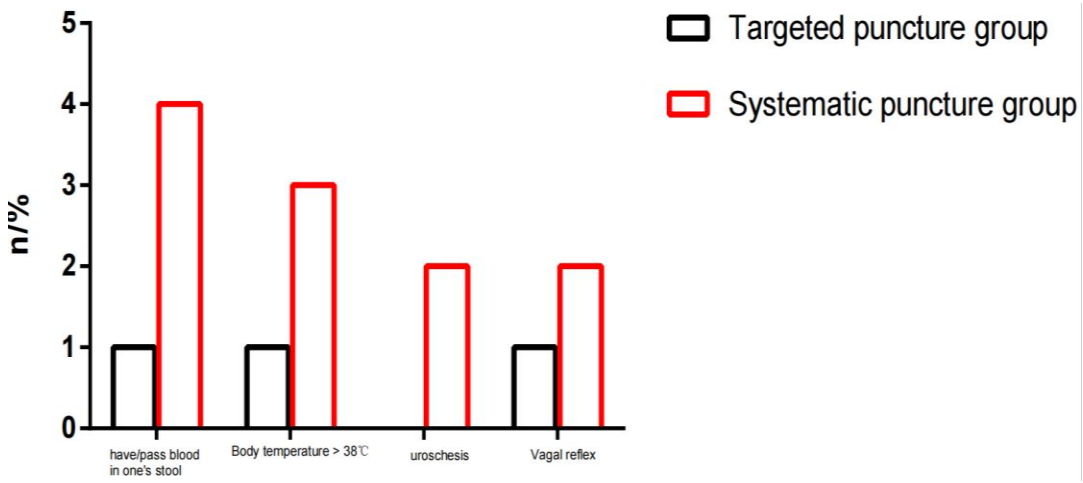

Figure 4: The complications between two puncture methods

4. Discussion

Prostate cancer (PCa) is the most prevalent malignant tumor affecting the male urinary system. According to statistics, around 1.4 million new cases of prostate cancer are expected to be diagnosed worldwide in the year 2020, with approximately 375,000 deaths resulting from the disease (Sung et al., 2021). Global cancer statistics in 2020 show that the incidence and mortality of PCa in China ranks sixth and seventh among male malignant tumors in China respectively, with 115426 new cases and 51094 deaths (Schaeffer et al., 2021). Autopsy reports indicate that the incidence of PCa in men over 79 years old has even reached 59% (Kohaar et al., 2019). There are many risk factors for PCa, including ageing, family history of malignancy, BRCA gene mutation, Lynch syndrome, prostatitis and benign prostatic hyperplasia. In addition, smoking, obesity and certain nutritional factors may increase the risk of advanced PCa (Vietri et al., 2021). Prostate biopsy is a necessary condition to giagnose PCa. Because of the low sensitivity and specificity of TRUS in the diagnosis of PCa, accurate targeted biopsy of PCa cannot be carried out under the guidance of TRUS. Borghesi et al. reviewed the complications of systematic prostate biopsy guided by TRUS (Borghesi et al., 2017). The incidence of acute urinary retention was about 11.7%-11.1% in patients with hematuria lasting more than 3 days, and was positively correlated with the number of puncture needles. Ehdaie et al (Ehdaie et al., 2014) and Loeb et al (Loeb et al., 2013) found that the incidence of septicemia and other severe infections in patients with repeated puncture was remarkably higher than that in patients with initial puncture. Therefore, increasing the detection rate of PCa and reducing the number of puncture and needle are the hotspots in the research of prostate puncture biopsy. MpMRI can improve the detection rate of PCa lesions by imaging examination, and the detection rate of PCa lesions with Gleason score ≥ 7 and tumor diameter ≥ 1cm can reach 85% to 95% (Ballesteros Ruiz et al., 2022). At present, mpMRI is an imaging technique with high resolution, high sensitivity, and high specificity in PCa screening. The mpMRI can accurately detect the location and characterization of PCa, carry out risk stratification, and provide accurate image guidance for prostate targeted biopsy, so it is widely used in the early diagnosis and treatment of PCa. The application of MRI-TRUS-assisted prostate biopsy technology has compensated for the inadequacy of the previous systematic random sampling and has remarkably improved the detection rate of adenocarcinoma. It is especially advantageous in patients with persistent elevated PSA who need repeated puncture, patients with early PCa who need active monitoring and patients with tumors in the anterior prostate region. Compared with the latter two MRI-assisted puncture techniques, MRI-TRUS cognitive fusion targeted puncture biopsy technology has lower requirements for hardware equipment, while considering the advantages of fast and simple operation, so it has been widely used. Brown et al. found in a large cohort study that the detection rate of PCa by MRI-TRUS cognitive fusion biopsy was 18% higher compared to prostate biopsy guided by

TRUS alone (Brown et al., 2018). Pepe et al. compared the detection rate of clinically meaningful PCa by targeted perineal and transrectal biopsy guided by MRI-TRUS cognitive fusion in a prospective study (Pepe et al., 2017). The results indicated that a total of 55 clinically remarkable prostate cancers were detected in 150 patients, of which 49 (89.1%) were detected by trans-perineal approach and 43 (78.1%) by transrectal approach. Therefore, combined with the actual situation of our hospital, this study also uses the MRI-TRUS cognitive fusion biopsy technique of trans-perineal approach. Lee et al. retrospectively analyzed the clinical data of 711 patients who went through prostate biopsy (Lee et al., 2021). It was found that PCa was detected in 201cases (28.3%) by combined biopsy, which was more than that of targeted biopsy (24.6%) or systematic puncture (17.4%). It was considered that when there were suspicious lesions on mpMRI. A combined puncture biopsy is more likely to detect clinically meaningful PCa in an initial prostate biopsy. In a retrospective analysis of 506 patients who underwent prostate biopsy, it was found that the total detection rate of PCa by standard systematic biopsy and targeted biopsy was similar. Specifically, the detection rate was 57.7% for standard systematic biopsy and 54.0% for targeted biopsy (Hanna et al., 2019), while the detection rate of clinically remarkable PCa was 24.7% and 30.8% respectively. Out of the 185 patients diagnosed with clinically significant PCa, 29 of them (15.7%) would not have been detected if only targeted biopsy was performed, which is consistent with the findings of previous studies. The results of this study indicated that no remarkable difference was found in the detection rate of PCa between targeted biopsy and systematic biopsy. The detection rate of targeted biopsy for high-risk PCa was higher compared to systematic biopsy, while the detection rate of patients with low-risk PCa was lower compared to systematic biopsy. Compared with systematic biopsy, targeted biopsy remarkably increases the detection rate of high-risk PCa and reduces the detection rate of low-risk PCa. The advantage of targeted puncture biopsy is that the predictive value of MRI for patients with medium-and high-risk PCa is more than 90% (Matsui et al., 2022; Mohler & Antonarakis, 2019), and targeted biopsy can achieve the detection of PCa, especially high-risk PCa with fewer needle numbers. In addition, it was found that no remarkable difference was found in the detection rate of medium-risk PCa between the two puncture methods. It was also found that no remarkable difference was found in puncture positive rate between the two puncture methods in different tPSA and Gleason scores. The proportion of positive needles in targeted puncture is greater than that in systematic puncture. Compared to systematic puncture biopsy, targeted puncture biopsy has the same detection rate of PCa, with remarkably fewer stitches to puncture, which helps to reduce the incidence of puncture-related complications. Previous studies have pointed out that systematic biopsy is blind, but targeted biopsy is more in line with the concept of accurate medicine. And fewer needles greatly reduce the risk of complications of transrectal puncture, such as pain, severe bleeding, and infection. Our study indicated that 1 patient

had hematochezia 3 days after targeted puncture, 1 patient had body temperature > 38 ℃, and 1 patient had vagus nerve reflex during or after puncture. The total incidence of complications was 2.30%. After systematic puncture, 4 patients had hematochezia, 3 patients with body temperature > 38 ℃, 2 patients with urinary retention and 2 patients with vagus nerve reflex. The incidence of complications was 8.40%. The risk of complications following targeted puncture is lower compared to systemic puncture, mainly because targeted puncture is less invasive and does not cause remarkable damage to normal tissue. It is important to note that routine fusion targeted biopsy should include systematic biopsy to prevent missing a significant number of clinically significant prostate cancers.

5. Conclusion

This study highlights the significant advantages of targeted prostate biopsy using cognitive fusion imaging in primary hospital settings. By combining the precision of multiparametric magnetic resonance imaging (mpMRI) with the practicality of transrectal ultrasound (TRUS), cognitive fusion imaging enhances the accuracy of pathological examinations for prostate cancer diagnosis while minimizing procedural complications. The findings demonstrate that this technique reduces false-negative rates, decreases the number of biopsy cores required, and lowers the incidence of adverse events such as hematuria and infection, making it a safer and more efficient diagnostic approach compared to conventional systematic biopsy. The study also underscores the broader implications of cognitive fusion imaging for patient recovery and quality of life. By reducing the invasiveness of the biopsy procedure, this method facilitates faster recovery times, enabling patients to resume physical activity and daily routines more quickly. This is particularly relevant for individuals with active lifestyles or those undergoing rehabilitation, as it supports physical resilience and minimizes disruptions to their overall health and well-being. Incorporating cognitive fusion imaging into primary care settings represents a step forward in democratizing access to advanced diagnostic techniques, bridging the gap between cutting-edge medical technologies and real-world clinical practice. Its cost-effectiveness and practicality make it a viable option for improving diagnostic outcomes in resource-constrained environments, ensuring that patients receive timely and accurate care regardless of their location. Future research should focus on long-term outcomes of patients diagnosed using cognitive fusion imaging, particularly its impact on treatment decisions, survival rates, and functional health. Additionally, exploring the integration of this technique with emerging technologies such as artificial intelligence could further enhance its diagnostic capabilities and accessibility. In conclusion, targeted prostate biopsy using cognitive fusion imaging is a transformative approach that not only improves diagnostic precision but also prioritizes patient safety and recovery. Its implementation in primary hospitals has the potential to redefine standards of

care for prostate cancer diagnosis, contributing to better health outcomes and quality of life for patients. This study provides a foundation for expanding the use of this innovative technique, emphasizing the importance of accessible, accurate, and patient-centered diagnostic solutions in modern healthcare.

Funding

Qinhuangdao Science and Technology Research and Development Program/ Qinhuangdao Health and Health Commission, Wei Xuefeng 201902A097.

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