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Is targeted biopsy really needed when performing systematic prostate biopsy to raise the detection rate for prostate cancer in patients with prostate-specific antigen ≤10 ng/mL?

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Abstract

Targeted biopsy with multiparametric magnetic resonance imaging and hypoechoic lesions on transrectal ultrasound has been implemented to increase prostate cancer detection rate.

We compared the detection abilities of systematic prostate biopsy, hypoechoic lesion-targeted biopsy (HL-TBx), and cognitive magnetic resonance imaging-targeted biopsy (MRI-TBx) in patients with suspected prostate cancer. Between September 2014 and August 2016, 193 patients with a prostate-specific antigen level of 3 to 10 ng/mL underwent HL-TBx or MRI-TBx. In patients who refused magnetic resonance imaging examination before prostate biopsy, HL-TBx was performed. We compared cancer detection rates and pathologic outcomes between systematic prostate biopsy and HL-TBx or MRI-TBx.

The cancer detection rates for HL-TBx and MRI-TBx were 40.8% and 43.8%, respectively, without a significant difference ($P = .683$). Of the 81 patients diagnosed with prostate cancer, most patients (77 patients, 95.1%) were diagnosed with prostate cancer by systematic prostate biopsy. The detection ability for prostate cancer was significantly better for systematic prostate biopsy than for HL-TBx or MRI-TBx ($P < .001$).

The detection abilities for clinically significant prostate cancer similar between HL-TBx and systematic prostate biopsy. Systematic prostate biopsy alone should be recommended for detection prostate cancer in patients with a prostate-specific antigen ≤10 ng/mL.

Abbreviations: DRE = digital rectal examination, HL-TBX = hypoechoic lesion-targeted biopsy, IRB = institutional review board, MRI-TBX = magnetic resonance imaging-targeted biopsy, PCa = prostate cancer, PSA = prostate-specific antigen, PV = prostate volume, TRUS = transrectal ultrasound.

Keywords: hypoechoic lesion, magnetic resonance imaging, transrectal ultrasound

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No complex statistical methods were applied in this paper.

The institutional review board waived the need for written informed consent because of the retrospective nature of this study.

The study design and protocols received institutional review board approval (IRB number: 3-2016-0151).

None of the study subjects or cohorts has been previously reported.

Methodology: retrospective, observational, performed at 1 institution.

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Key Points

- Hypoechoic lesion- and MRI-targeted biopsies were inferior to systematic biopsy.
- Systematic prostate biopsy alone should be recommended for detecting prostate cancer.
- Targeted biopsy adds little clinical value despite its greater cost and time.

1. Introduction

Transrectal ultrasound (TRUS)-guided systematic prostate biopsy (SBx) of 12 cores is the standard biopsy approach for men with suspected prostate cancer (PCa). However, approximately 30% of men with clinically detectable PCa are not diagnosed in the initial biopsy.[1] To raise cancer detection rates, physicians could perform magnetic resonance imaging (MRI)-based targeted biopsy (TBx) using multiparametric MRI for guidance to areas suspicious of cancer.[2] However, MRI has not significantly increased the accuracy of PCa risk prediction and is not recommended in the setting of first prostate biopsy.[3] Accordingly, we previously suggested the use of hypoechoic lesions on TRUS to raise PCa detection rates. Although hypoechoic lesions on TRUS are not an indication for prostate biopsy, this method has been shown to be effective.[4,5]

Targeted biopsy was suggested to avoid potentially unnecessary biopsies, thereby decreasing post-procedural risk and pain and, at the same time, increasing PCa detection rates. Thus, many studies have focused on evaluating the efficacy of TBx using not only MRI but also TRUS.[5] However, TBx cannot be performed independently of SBx and should only be used as a supplementary method under the assumption that it would raise the PCa detection rate according to the National Comprehensive Cancer Network guidelines.[4] Indeed, there is no consensus on when TBx should be performed and on whether TBx is truly needed when performing SBx. In an effort to help reach a consensus, we performed SBx with TBx by TRUS hypoechoic lesion-targeted biopsy (HL-TBx) and MRI-TBx and compared PCa detection rates and pathologic outcomes (under the same numbers of cores for HL-TBx and MRI-TBx) in patients with a prostate-specific antigen (PSA) level of less than 10 ng/mL.

2. Patients and methods

2.1. Study population and data collection

Institutional review board (IRB) approval was obtained (IRB number: 3-2016-0151), and the requirement for informed consent was waived owing to the retrospective nature of this study. We reviewed the records of 205 patients with a PSA level ≤10 ng/mL who underwent targeted prostate biopsy, including both HL-TBx and MRI-TBx, at our institution from September 2014 to August 2016. Twelve patients with a prior diagnosis of PCa were excluded. The remaining 193 patients were included in the analysis.

Data on the following clinical and pathological features were collected: age, history of previous prostate biopsy, prostate volume (PV), PSA, PSA density, and clinical and pathological disease staging according to the 7th edition of the American Joint Committee on Cancer.

2.2. Indications and protocol for prostate biopsy

The indications for prostate biopsy were an elevated PSA level (≥3 ng/mL), a steadily increasing PSA level, or an abnormal digital rectal examination (DRE). We explained the risks and benefits of MRI to patients with suspected PCa. We performed MRI in those who agreed to the evaluation. The MRI examination included diffusion-weighted imaging, dynamic contrast-enhanced imaging, and routine prostate MRI obtained in 3 orthogonal planes (axial, sagittal, and coronal), and it was performed using a 3.0-Tesla MRI scanner (Intera-Achieva 3.0T, Phillips Medical System, Best, the Netherlands) equipped with a phased-array coil (6-channel). Two *b* values (0–1000) were used, and diffusion restriction was quantified using apparent diffusion coefficient mapping. All images were interpreted by 2 uroradiologists. If the conclusions of the 2 reviewers differed, they discussed the findings and reached a consensus. In patients with no visible lesions on MRI, an additional precise PSA follow up was recommended instead of immediate prostate biopsy; these patients were excluded in this study. In patients who refused the MRI examination, HL-TBx was performed at hypoechoic lesions on TRUS.

All prostate biopsies were performed by a single urologist with over 150 cases of experience in MRI-TBx to reduce bias. For a single patient, either HL-TBx or MRI-TBx was performed for 2 cores. After all TBx procedures, SBx with 12 cores was performed. For HL-TBx, a hypoechoic lesion on TRUS was defined as a region with hypoechogenicity relative to the surrounding tissue. In HL-TBx, 2 hypoechoic lesions were selected based on the operator's discretion, and 1 core for each hypoechoic lesion was obtained. For MRI-TBx, 2 cores for a targeted lesion were obtained. If the target regions coincided with systemic biopsy regions, target regions were given priority. The volume per core ratio was calculated as the PV divided by the number of biopsy cores. Significant PCa was defined as

(1) a Gleason score ≥7,
(2) nonorgan-confinement (presence of extracapsular extension and seminal vesicle or lymph node involvement), or
(3) a tumor volume ≥0.5 cc.[6,7]

2.3. Statistical analysis

Continuous variables are expressed as medians (interquartile ranges), and categorical variables are reported as the number of occurrences and frequency. Student *t* test and the Chi-square test were used to evaluate differences in continuous and categorical variables, respectively. Cancer detection rates were compared between the examinations using the McNemar test. Univariate and multivariate logistic regression analyses were performed, and variables that were significant in the univariate analysis were included in the multivariate analysis. The HL-TBx and MRI-TBx groups were matched on a 1:1 basis using propensity scores (41 patients in each group). Statistical analyses were performed using SPSS, version 23.0 (SPSS Inc, Chicago, IL). All *P*-values <.05 were considered to indicate statistical significance.

3. Results

The baseline characteristics of the 193 patients are presented in Table 1. A total of 120 patients underwent HL-TBx, and 73 patients underwent MRI-TBx. The number of biopsy cores was 14 in both groups. A total of 81 patients (42.0%) was diagnosed with PCa, and the detection rates did not significantly differ between the HL-TBx and MRI-TBx groups (40.8% vs 43.8%, *P* = .683). Of the patients diagnosed with PCa (81 patients), most patients (77 patients, 95.1%) were diagnosed with PCa by SBx.

Multivariate logistic regression analysis showed age (odds ratio [OR] = 1.07 [95% confidence interval: 1.026–1.111], *P* = .001) and PV (OR = 0.95 [0.924–0.971], *P* < .001) to be

Table 1

Basic characteristics of the patients according to the biopsy method.

	HL-TBx	MRI-TBx	*P*-value
Number of patients	120	73	
Age, yr	65.8 (59.5–73.2)	65.5 (60.2–70.7)	.806
Previous PBx history (yes)	14 (11.7)	20 (27.4)	.006
PSA (ng/mL)	5.44 (4.29–6.34)	6.14 (4.83–7.95)	.015
Prostate volume (cc)	40.4 (29.7–49.8)	41.5 (31.1–56.3)	.275
PSA density (ng/mL/cc)	0.14 (0.10–0.19)	0.15 (0.11–0.20)	.292
Volume per core (cc/core)	2.94 (2.20–3.64)	2.73 (1.92–3.69)	.179
Cancer detection	49 (40.8)	32 (43.8)	.685
Patients with positive SBx	46 (93.9)	31 (96.9)	.572
Patients with positive TBx	20 (40.8)	15 (46.9)	.500

Data are shown as number (%) or median (interquartile range).
DRE = digital rectal examination, HL-TBx = hypoechoic lesion-targeted biopsy, MRI-TBx = cognitive magnetic resonance imaging-targeted biopsy, PBx = prostate biopsy, PSA = prostate-specific antigen, SBx = systematic prostate biopsy, TBx = targeted biopsy.

Table 2

Clinical features of patients according to the biopsy method after propensity-score matching.

	HL-TBx (n = 41)	MRI-TBx (n = 41)	*P*-value
Cancer detection	18 (43.9)	19 (46.3)	.825
Age, yr	64.3 (59.9–66.9)	65.5 (61.8–71.9)	.537
Previous PBx history (yes)	10 (24.4)	12 (29.3)	.734
PSA (ng/mL)	6.15 (5.37–7.44)	6.42 (4.97–8.13)	.423
Abnormal DRE	5 (12.2)	6 (14.6)	.647
Prostate volume (cc)	39.6 (27.6–49.4)	42.9 (30.1–56.8)	.256
PSA density (ng/mL/cc)	0.15 (0.12–0.22)	0.16 (0.11–0.23)	.187
Volume per core (cc/core)	2.95 (2.06–3.74)	2.58 (2.04–3.75)	.711
Patients with positive SBx	18/41 (43.9)	19/41 (46.3)	.825
Lesions with positive TBx	25/82 (30.5)	36/82 (43.9)	.016

Data are shown as number (%) or median (interquartile range).

DRE = digital rectal examination, HL-TBx = hypoechoic lesion-targeted biopsy, MRI-TBx = cognitive magnetic resonance imaging-targeted biopsy, PBx = prostate biopsy, PSA = prostate-specific antigen, SBx = systematic prostate biopsy, TBx = targeted biopsy.

independent predictors of PCa detection; however, the biopsy method was not a significant predictor of PCa detection. Cancer detection and pathologic outcomes were further compared between biopsy methods. Propensity-score matching was performed using multivariate logistic regression on the basis of the following covariates: age, previous prostate biopsy history, PSA, DRE, and PV (Table 2). This analysis included 41 patients in each group, and there were no group differences in cancer detection rate (43.9% vs 46.3%, $P = .825$), age, previous prostate biopsy history, PSA, abnormal findings on DRE, or PV. Although there was no difference in the number of patients with a positive SBx (18 vs 19, $P = .825$), the positive target lesion rate was higher in the MRI-TBx group than in the HL-TBx group (30.5% vs 43.9%, $P = .016$).

Subgroup analysis of individual biopsy methods was performed to compare PCa detection rates between SBx and HL-TBx. The positive rates of SBx and HL-TBx for PCa were 38.3% (46/120 patients) and 16.7% (20/120 patients), respectively ($P < .001$). In the comparison of PCa detection rates between SBx and MRI-TBx, the positive rates for PCa were 42.5% (31/73 patients) and 20.5% (15/73 patients), respectively ($P < .001$). In the TBx groups, 3 patients (6.1%) in the HL-TBx group and 1 patient (3.1%) in the MRI-TBx group were diagnosed with PCa by TBx alone (Table 3).

In the comparison of detection rates for clinically significant PCa between SBx and HL-TBx, the positive rates of SBx and HL-TBx were 17.5% (21/120 patients) and 10.8% (13/120 patients), respectively, without a significant difference ($P = .453$). However, in the comparison between SBx and MRI-TBx, the detection rates of SBx and MRI-TBx were 17.5% (21/120) and 9.1% (11/120), respectively ($P < .001$). There were 5 patients (4.2%) with insignificant SBx results but significant TBx results in the HL-TBx group, but only 1 patient (1.4%) in the MRI-TBx group (Table 4).

4. Discussion

The present study is first to investigate whether SBx alone could provide sufficient performance in the detection of PCa, without the help of TBx, regardless of the biopsy methods, in a group of patients with a PSA level $\leq$10 ng/mL. For these patients, performing only SBx was sufficient for primarily detecting PCa with relatively good performance. TBx added little value in increasing detection rates, despite its greater cost and time to complete the procedure. If MRI has been performed, considering MRI-TBx in addition to SBx would help increase detection rates, although the difference in detection rates for SBx and MRI-TBx

Table 3

Comparison of SBx with HL-TBx or MRI-TBx for the detection of prostate cancer.

	TBx			
	HL-TBx		MRI-TBx	
	Negative for cancer (patients, n, %)	Positive for cancer (patients, n, %)	Negative for cancer (patients, n, %)	Positive for cancer (patients, n, %)
SBx				
Negative for cancer (patients, n, %)	71 (59.2%)	3 (2.5%)	41 (56.2%)	1 (1.4%)
Positive for cancer (patients, n, %)	29 (24.2%)	17 (14.2%)	17 (23.3%)	14 (19.2%)
	$P < .001$	$P < .001$		

The *P*-value was calculated using the McNemar test.

HL-TBx = hypoechoic lesion-targeted biopsy, MRI-TBx = cognitive magnetic resonance imaging-targeted biopsy, SBx = systematic prostate biopsy.

Table 4

Comparison of SBx with HL-TBx or MRI-TBx for the detection of clinically significant prostate cancer.

	TBx			
	HL-TBx		HL-TBx	
	No/insignificant cancer (patients, n, %)	No/insignificant cancer (patients, n, %)	No/insignificant cancer (patients, n, %)	No/insignificant cancer (patients, n, %)
SBx				
No/Insignificant cancer (patients, n, %)	94 (78.3%)	5 (4.2%)	51 (69.9%)	1 (1.4%)
Clinically significant cancer (patients, n, %)	13 (10.8%)	8 (6.7%)	11 (15.1%)	10 (13.7%)
	$P = .096$	$P < .001$		

The *P*-value was calculated using the McNemar test.

HL-TBx = hypoechoic lesion-targeted biopsy, MRI-TBx = cognitive magnetic resonance imaging-targeted biopsy, SBx = systematic prostate biopsy.

in this study was not statistically significant. HL-TBx was deemed ineffective in improving detection rates above those achieved with SBx in this study, although other studies we have performed indicated that implementing quantitative values of hypoechoic lesions would increase detection rates.[5] Accordingly, we are planning to conduct a thorough cost-effectiveness analysis of HL-TBx for detecting PCa.

We performed SBx with 12 cores and TBx with 2 cores in all patients with a PSA level $\leq$10 ng/mL using MRI-TBx or HL-TBx. Only a few patients were not diagnosed with PCa by SBx; however, many of the PCa cases were not detected by TBx. This implies that the accuracy of accompanying imaging modalities should be improved to increase the prediction accuracy of TBx. Until then, SBx alone is suitable as a standard detection approach for PCa, without the need for TBx. Regarding the imaging modalities for TBx, we could not determine whether MRI or TRUS was superior in the present study.

Imaging modalities, including MRI, have been implemented in an attempt to increase PCa detection rates, and previous studies have reported that overall and clinically significant PCa detection rates are higher in SBx with MRI-TBx than in SBx alone.[8] However, our results showed that SBx alone could detect PCa overall with relatively good performance. Most of the PCa cases (95.1%) were detected by SBx, and only a small number (4.9%) were detected by TBx alone (Table 1).

While many studies have compared MRI-TBx with SBx, few have compared detection rates between MRI-TBx and HL-TBx. One study reported that the detection rates for HL-TBx and MRI-TBx were 40.8% and 46.9%, respectively, without significant differences and were comparable to the detection rate of initial biopsy of approximately 30%.[1] Another study indicated that approximately 30% to 35% of men with a PSA level of 4 to 10 ng/mL are diagnosed with PCa.[4] In the present study, the detection rates of 40.8% and 43.8% in the HL-TBx and MRI-TBx groups were relatively higher than those reported in previous studies. Although there was no difference in the overall detection rate between the methods, propensity-score matched analysis revealed that HL-TBx showed a lower positive target lesion rate than MRI-TBx with significance. This implied that MRI-TBx is more effective in detecting PCa than HL-TBx, and that HL-TBx should not be considered as an option for TBx, as it adds little value to SBx. Previous studies on HL-TBx have suggested that SBx should be performed regardless of echogenicity,[9,10,11] which is consistent with our results.

A previous study reported that patients with a hypoechoic lesion on TRUS show higher PSA levels, Gleason scores, and percentages of positive cores and that patients without hypoechoic lesions have better outcomes than patients with hypoechoic lesions.[12] Moreover, target lesions with hypoechogenicity on MRI-TRUS fusion biopsy yielded an increase in the detection of higher-grade PCa, compared to that achieved with the biopsy of MRI lesions alone.[13] Accordingly, hypoechoic lesions on TRUS have been considered as target lesions in MRI-TBx and set as additional targets. As such, we have focused on using quantitative values of hypoechoic lesions in TRUS to improve the accuracy and effectiveness of PCa detection ability by HL-TBx.[5] We reported that the grayscale values of hypoechoic lesions are significant predictive factors for PCa and high-grade disease.[5] The present study reported similar findings to those in our previous study regarding the efficacy of HL-TBx. Herein, HL-TBx detected clinically significant PCa in 5 patients that was not detected by SBx. In detecting clinically significant PCa, there was no difference between SBx and HL-TBx, supporting the efficacy of HL-TBx, if performed properly. We believe that we should not abandon HL-TBx and that additional research on the grayscale values of hypoechoic lesions would provide effective information on PCa.

The present study reaffirmed the efficacy of MRI-TBx described in recent studies.[14,15,16] One patient was diagnosed by MRI-TBx, but the diagnosis was missed by SBx. Moreover, 1 patient was diagnosed with clinically significant PCa by MRI-TBx, but, again, the diagnosis was missed by SBx. A recent multicenter clinical trial demonstrated that MRI-TBx was superior to standard SBx.[14] Similarly, our results showed the effectiveness of MRI in detecting PCa that, in some cases, SBx could not detect. The study by Kasivisvanthan and colleagues enrolled participants with a PSA less than 20 ng/mL, whereas our study enrolled patients with PSA less than 10 ng/mL, which may explain why the effectiveness of MRI was underestimated in our study, compared with other studies.[14] Regarding targeting modalities, lesions positive on TBx were significantly more frequent on MRI-TBx than on HL-TBx after propensity-score matching. However, HL-TBx also showed good performance in detecting clinically significant PCa in 5 patients in whom PCa detection was missed by SBx, and there was no statistically significant difference between SBx and HL-TBx in detecting clinically significant PCa.

We should not depend solely on TBx for detecting PCa, and TBx cannot totally replace SBx due to the underestimation of PCa by MRI. A recent study reported that MRI underestimated histologically determined tumor boundaries in 46 tumor lesions from 33 patients who underwent 3.0-Tesla MRI and prostatectomy.[17] Moreover, among 1895 patients who underwent radical prostatectomy at our institution, 242 (12.8%) patients had negative findings on MRI.[18] Therefore, until imaging modalities for PCa advance further, clinicians should not solely depend on MRI and MRI-TBx and should consider SBx.

The present study has several limitations. First, the present study was not designed as a randomized controlled study with high-level evidence. Individual patient factors, such as educational status and economical and social backgrounds, might affect clinical decision-making on whether or not to perform MRI examination. Nevertheless, we believe that this variation may reflect actual clinical practice. Second, the prostate imaging reporting and data system (PI-RADS) version was changed during the study period. We could not uniformly apply the same version due to the limitation of the retrospective study design, and analyzing PI-RADS would produce different results in the detection rate of lesions according to PI-RADS score. Therefore, we analyzed the detection rate of suspicious lesions and did not compare the detection rate of MRI-TBx in the present study with that in previous studies. Third, we included patients with previous biopsy history to increase the size of the study population. However, we could not document the time between previous biopsy, since most of the patients with previous biopsy history visited our institution after the first prostate biopsy at other hospitals and since the exact medical records were missing. Finally, this retrospective study was based on a single operator's experience. Hence, our results might not be applicable to other HL-TBx series. Considering that the selection of hypoechoic lesions may differ according to the operator, a larger series or a multi-institutional study may address this limitation in the future.

In conclusion, SBx alone should be primarily recommended for the detection of PCa. Although TBx would help increase the PCa

detection rate, it adds little value considering its cost and time. We believe that the development of more sophisticated methods for the quantitation of hypoechoic lesions would result in a more affordable PCa diagnostic tool.

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References

[1] Scattoni V, Zlotta A, Montironi R, et al. Extended and saturation prostatic biopsy in the diagnosis and characterisation of prostate cancer: a critical analysis of the literature. Eur Urol 2007;52:1309–22.
[2] Birs A, Joyce PH, Pavlovic ZJ, et al. Diagnosis and monitoring of prostatic lesions: a comparison of three modalities: multiparametric MRI, fusion MRI/transrectal ultrasound (TRUS) and traditional TRUS. Cureus 2016;8:e702.
[3] Cormio L, Cindolo L, Troiano F, et al. Development and internal validation of novel nomograms based on benign prostatic obstruction-related parameters to predict the risk of prostate cancer at first prostate biopsy. Front Oncol 2018;8:438.
[4] Carroll PR, Parsons JK, Andriole G, et al. NCCN guidelines insights: prostate cancer early detection, version 2.2016. J Natl Compr Canc Netw 2016;14:509–19.
[5] Lee KS, Koo KC, Chung BH. Quantitation of hypoechoic lesions for the prediction and Gleason grading of prostate cancer: a prospective study. World J Urol 2018;36:1059–65.
[6] Epstein JI, Walsh PC, Carmichael M, et al. Pathologic and clinical findings to predict tumor extent of nonpalpable (stage T1c) prostate cancer. JAMA 1994;271:368–74.
[7] Ploussard G, Epstein JI, Montironi R, et al. The contemporary concept of significant versus insignificant prostate cancer. Eur Urol 2011;60: 291–303.
[8] Schoots IG, Roobol MJ, Nieboer D, et al. Magnetic resonance imaging–targeted biopsy may enhance the diagnostic accuracy of significant prostate cancer detection compared to standard transrectal ultrasound-guided biopsy: a systematic review and meta-analysis. Eur Urol 2015;68:438–50.
[9] Hammerer P, Huland H. Systematic sextant biopsies in 651 patients referred for prostate evaluation. J Urol 1994;151:99–102.
[10] Heijmink SW, van Moerkerk H, Kiemeney LA, et al. A comparison of the diagnostic performance of systematic versus ultrasound-guided biopsies of prostate cancer. Eur Radiol 2006;16:927–38.
[11] Vallancien G, Prapotnich D, Veillon B, et al. Systematic prostatic biopsies in 100 men with no suspicion of cancer on digital rectal examination. J Urol 1991;146:1308–12.
[12] Nakano Junqueira VC, Zogbi O, Cologna A, et al. Is a visible (hypoechoic) lesion at biopsy an independent predictor of prostate cancer outcome? Ultrasound Med Biol 2012;38:1689–94.
[13] Shakir NA, Siddiqui MM, George AK, et al. Should hypoechoic lesions on transrectal ultrasound be sampled during magnetic resonance imaging-targeted prostate biopsy? Urology 2017;105:113–7.
[14] Kasivisvanthan V, Rannikko AS, Borghi M, et al. MRI-targeted or standard biopsy for prostate-cancer diagnosis. N Engl J Med 2018;378: 1767–77.
[15] Moore CM, Robertson NL, Arsanious N, et al. Image-guided prostate biopsy using magnetic resonance imaging–derived targets: a systematic review. Eur Urol 2013;63:125–40.
[16] Pokorny MR, de Rooij M, Duncan E, et al. Prospective study of diagnostic accuracy comparing prostate cancer detection by transrectal ultrasound-guided biopsy versus magnetic resonance (MR) imaging with subsequent MR-guided biopsy in men without previous prostate biopsies. Eur Urol 2014;66:22–9.
[17] Le Nobin J, Rosenkrantz AB, Villers A, et al. Image guided focal therapy for magnetic resonance imaging visible prostate cancer: defining a 3-dimensional treatment margin based on magnetic resonance imaging histology co-registration analysis. J Urol 2015;194:364–70.
[18] Chung DY, Koh DH, Goh HJ, et al. Clinical significance and predictors of oncologic outcome after radical prostatectomy for invisible prostate cancer on multiparametric MRI. BMC Cancer 2018;18:1057.