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ORIGINAL ARTICLE

Optimizing multiparametric magnetic resonance imaging-targeted biopsy and prostate cancer grading accuracy

Romain Diamand[1] · Alexandre Peltier[1] · Jean-Baptiste Roche[2] · Elena Lievore[2,3] · Vito Lacetera[4] · Giuseppe Chiacchio[4] · Valerio Beatrici[4] · Riccardo Mastroianni[5] · Giuseppe Simone[5] · Olivier Windisch[6] · Daniel Benamran[6] · Alexandre Fourcade[7] · Truong An Nguyen[7] · Georges Fournier[7] · Gaelle Fiard[8] · Guillaume Ploussard[9] · Thierry Roumeguère[1] · Simone Albisinni[1]

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Abstract

Purpose To assess the most efficient biopsy method to improve International Society of Urological Pathology (ISUP) grade group accuracy with final pathology of the radical prostatectomy (RP) specimen in the era of magnetic resonance imaging (MRI)-driven pathway.

Methods A total of 753 patients diagnosed by transrectal MRI-targeted and systematic biopsies (namely "standard method"), treated by RP, between 2016 and 2021 were evaluated. Biopsy methods included MRI-targeted biopsy, side-specific systematic biopsies relative to index MRI lesion and combination of both. Number of MRI-targeted biopsy cores and positive cores needed per index MRI lesion were assessed. Multivariable analysis was performed to analyze predictive factors of upgrading using MRI targeted and ipsilateral systematic biopsies method.

Results Overall, ISUP grade group accuracy varied among biopsy methods with upgrading rate of 35%, 49%, 27%, and 24% for MRI targeted, systematic, MRI targeted and ipsilateral systematic biopsies and standard methods, respectively ($p < 0.001$). A minimum of two positive MRI-targeted biopsies cores per index MRI lesion were required when testing MRI targeted and ipsilateral systematic biopsies method to reach equivalent accuracy compared to standard method. Omitting contralateral systematic biopsies spared an average of 5.9 cores per patient. At multivariable analysis, only the number of positive MRI-targeted biopsy cores per index MRI lesion was predictive of upgrading.

Conclusion MRI targeted and ipsilateral systematic biopsies allowed an accurate definition of ISUP grade group and appears to be an interesting alternative when compared with standard method, reducing total number of biopsy cores needed.

Keywords MRI-targeted biopsy · Prostate cancer · Upgrading · Number of cores · Radical prostatectomy

✉ Romain Diamand
romain.diamand@bordet.be

[1] Department of Urology, Jules Bordet Institute-Erasme Hospital, Hôpital Universitaire de Bruxelles, Université Libre de Bruxelles, Rue Meylemeersch 90, 1070 Brussels, Belgium

[2] Department of Urology, Clinique Saint-Augustin, Bordeaux, France

[3] Department of Urology, IRCCS IEO Istituto Europeo di Oncologia, Mila, Italy

[4] Department of Urology, Azienda Ospedaliera Ospedali Riuniti Marche Nord, Pesaro, Italy

[5] Department of Urology, IRCCS "Regina Elena" National Cancer Institute, Rome, Italy

[6] Department of Urology, Hôpitaux Universitaires de Genève, Geneva, Switzerland

[7] Department of Urology, Hôpital Cavale Blanche, CHRU Brest, Brest, France

[8] Department of Urology, Grenoble Alpes University Hospital, Université Grenoble Alpes, CNRS, Grenoble INP, TIMC, Grenoble, France

[9] Department of Urology, La Croix du Sud Hospital, Quint Fonsegrives, France

Introduction

The current international guidelines recommend performing multiparametric magnetic resonance imaging (MRI) in patients with clinical suspicion of prostate cancer (PCa) and, when a suspicious MRI lesion is reported, a combination of MRI targeted and systematic biopsies [1]. Omitting systematic biopsy is known to be associated with a risk of missing clinically significant PCa and decreased International Society of Urological Pathology (ISUP) grade group concordance at radical prostatectomy (RP) [2–4]. Hence, they should not be avoided, although associated with an increased total number of cores taken, biopsy-related complications, and subsequent cost [5, 6].

The optimal biopsy strategy, in terms of spatial distribution and number of cores that need to be taken, has not been yet clearly defined. In particular, at least eight systematic biopsies should be performed bilaterally depending on prostate volume whereas 3–5 targeted biopsies are needed to compensate the risk of targeting imprecision [7–10]. On the other hand, the recent studies suggested that distant systematic biopsy cores relative to index MRI lesion only play a limited role in csPCa detection [11–13]. In addition, a preliminary study has shown similar grading accuracy for MRI-targeted biopsy associated with perilesional biopsy taken in close proximity to index MRI lesion as compared to the standard template [14]. The number of MRI-targeted biopsy cores also appears to be correlated with the rate of upgrading at final pathology [15, 16].

The aim of this study was to assess several biopsy methods and define the most efficient in terms of cores number and location in order to improve ISUP grade group accuracy.

Patients and methods

Study population

After obtaining institutional review boards approval, side-specific data from 767 patients who sequentially underwent MRI, MRI-targeted and systematic biopsy (namely "standard method") within the year before RP for clinically localized PCa between January 2016 and November 2021 were retrospectively identified from prospectively maintained databases at eight European tertiary referral-centers (Belgium, France, Italy, Switzerland). No patients received neoadjuvant hormonal therapy. Among these, we excluded patients with incomplete information on pathological data and ISUP grade group ($n = 14$). The indication for surgical intervention with or without extended pelvic lymph node dissection was left to the discretion of the treating physician after exploring all treatment options.

MRI and biopsy procedures

All prebiopsy MRI were performed with the use of 1.5-T or 3-T scanner, with or without an endorectal coil, and consisted of multiplane T1- and T2-weighted imaging, diffusion-weighted imaging and dynamic contrast enhancement according to the European Society of Urogenital Radiology guidelines [17]. MRI scans were reviewed and scored by a dedicated genitourinary radiologist using the PI-RADS v.2 or 2.1 protocols (Supplementary Table 1) [18–20]. Suspicious lesions, defined as PI-RADS score ≥ 3, and prostate contours were manually contoured on T2-weighted sequence by radiologists and submitted to biopsy platform. Transrectal MRI-targeted biopsies were carried out with the KOELIS system (KOELIS®, La Tronche, France) allowing MRI-3D ultrasound images fusion by urologists dedicated to fusion biopsy using Urostation® or Trinity® software platforms. MRI-targeted and systematic biopsies were performed during the same session and the number of cores taken depended on patient characteristics and physician preferences. Both individual biopsy cores and whole-mount prostatectomy specimens were analyzed by dedicated genitourinary pathologist using the ISUP 2014 recommendations [21].

Covariates definition and outcomes

Patient characteristics were obtained on PSA, clinical stage at digital rectal examination (DRE), prostate volume calculated on MRI using ellipsoid formula and PSA density (PSAd). Radiological features were the side of MRI lesion, PI-RADS score, maximum lesion diameter of index MRI lesion, and clinical stage at MRI. Index MRI lesion was defined as the lesion with the highest PI-RADS score or the largest maximum diameter in case of multiple suspicious lesions. If index MRI lesion crosses the midline, the side was defined using the center of the lesion ($n = 13$). Radiological experience was defined as center fulfilled all criteria of expertise as described by ESUR/ESUI consensus statements [20]. Biopsy information were the location of cores after reviewing each patient-specific 3D prostate map generated by KOELIS system, number of cores, number of positive cores, and overall ISUP grade group according to the ISUP 2014 consensus and taking into account the highest grade on MRI targeted or systematic biopsy [21]. Clinically significant PCa(csPCa) was defined as ISUP grade group ≥ 2. Low-, intermediate and high-risk categories were assigned according to EAU guidelines and clinical stage was based on the DRE [1]. We compared ISUP grade group and risk categories at whole-mount prostatectomy specimen with biopsy

findings. The outcome of the study was the rate of upgrading at final pathology, defined by an ISUP grade group higher than the one described on preoperative biopsy.

Statistical analysis

Descriptive statistics were presented using frequency for categorical variable and median with interquartile range(IQR) for continuous variable. ISUP grade group and risk categories accuracies (i.e., downgrading, concordance, and upgrading) were compared according to the biopsy method (Supplementary Fig. 1). The rates of ISUP grade group upgrading were presented according to the number of MRI-targeted biopsy cores taken in the index MRI lesion and the number of positive cores. Mann – Whitney and χ^2 tests were used as appropriate to compare medians and frequencies between independent groups, respectively. Uni- and multivariable logistic regression analysis was used to assess predictive factors of ISUP grade group upgrading. We selected covariates for multivariate model using $p < 0.1$ in the univariate analysis. A two-sided $p < 0.05$ defined statistical significance. All statistical analysis was performed with STATA 14.1 (StataCorp, Texas, USA).

Results

Characteristics of the 753 patients included in the study are presented in Table1. The median preoperative PSA was 7 ng/ml (5.2–9.8), the majority of patients had a nonpalpable tumor defined as cT1 (69%) and the median prostate volume was 45 cc (34–57). The median number of MRI-targeted biopsy cores in the index MRI lesion was 4 (3–5), including 3 (2–4) positive cores. Median numbers of ipsilateral and contralateral systematic biopsies cores were 6 (4–6) and 6 (5–6), of which a median of 2 (0–3) were positive in the ipsilateral template and 0 (0–2) were positive in the contralateral template.

Distribution of ISUP grade group and risk categories accuracies are presented in Fig. 1. The combination of MRI-targeted and systematic biopsies was the most accurate biopsy method to compare RP with the lowest upgrading (24% and 13% for ISUP grade group and risk categories, respectively) and the highest concordance (60% and 77% for ISUP grade group and risk categories, respectively) rates. A similar trend was observed when combined MRI-targeted with ipsilateral systematic biopsies which seemed to be numerically comparable as the standard template (27% and 15% of upgrading for ISUP grade group and risk categories, respectively). Of note, similar downgrading rates were observed (17% and 10% for ISUP grade group and risk categories, respectively).

The rate of upgrading according to the number of MRI-targeted biopsy taken in the index MRI lesion is presented in Fig. 2. MRI-targeted biopsy alone was systematically associated with higher upgrading rate compared to other biopsy methods unless a minimum of four positive cores was obtained. Focusing on the MRI-targeted and ipsilateral systematic biopsy method, a minimum of two cores appeared necessary to match the accuracy of standard template whereas two positive cores seemed required to provide sufficient information to reduce upgrading rate. Subgroup analysis showed that more than two positive cores would be preferable for PI-RADS 3 lesions and those with a lesion maximum diameter < 10 mm (Supplementary Table 2).

Omitting contralateral systematic biopsy was associated with a 36% (4433/12196) decrease in the total number of biopsy cores which represent an average of 5.9 fewer cores per patient. Using this method, 2.3% (17/753) PCa and 1.8% (14/753) csPCa would be missed. Among those missing PCa, we found that prostate volume was higher (54 cc [41–95] vs 44 [33–57], $p = 0.04$) and a lower number of MRI-targeted biopsies were taken (4 [2–4] vs 4 [4–6], $p = 0.03$) (Supplementary Fig. 2; Table 3).

At multivariable logistic regression analysis, the number of positive MRI-targeted biopsies (OR 0.87 [0.77–0.98], $p = 0.03$) and radiological experience (OR 0.39 [0.26–0.58], $p < 0.0001$) was predictive of upgrading at final pathology when testing MRI-targeted and ipsilateral systematic biopsies method (Supplementary Tables 4–5).

Discussion

The aim of the present study was to evaluate several biopsy methods and define the most efficient to improve ISUP grade group accuracy at radical prostatectomy specimens. We found that the number of positive MRI-targeted biopsies plays a significant role to reduce the risk of upgrading and matches standard template when combined with ipsilateral systematic biopsy, reducing the number of biopsy cores by approximately 6 per patient. These findings highlight the importance of regional biopsy saturation and the importance of adequate biopsy sampling (i.e., to obtain sufficient tissue specimen containing PCa) [22].

A previous systematic review and meta-analysis including 10 studies with 1215 men already reported that systematic biopsy was more likely to be upgraded compared to MRI-targeted biopsy for biopsy-naïve and patient with prior negative biopsy (odds ratio [OR] 1.6 [95% CI 1.02–2.27], $p < 0.001$, and 4.23 [95% CI 1.68–8.48], $p = 0.003$, respectively) [23]. Furthermore, the combination of both techniques is known to be more effective in terms of concordance (49–60%, 45–63% and 62–75% for systematic biopsy, MRI-targeted biopsy and both, respectively) and upgrading

Table 1 Descriptive characteristics of 753 patients with clinically localized PCa diagnosed with systematic and MRI-targeted biopsies before RP between 2016 and 2021

Parameter	Total ($n=753$)
Age at surgery (year), median (IQR)	66 (62–70)
Previous negative biopsy, *n*(%)	75 (0.1)
Preoperative PSA (ng/ml), median (IQR)	7 (5.2–9.8)
Clinical stage, *n*(%)	
cT1	518 (69)
cT2	212 (28)
cT3	11 (1.5)
Unknown	12 (1.6)
Prostate volume (cc), median (IQR)	45 (34–57)
PSA density (ng/ml/cc), median (IQR)	0.15 (0.11–0.24)
PI-RADS score, *n*(%)	
3	66 (8.8)
4	395 (52)
5	282 (39)
Maximum diameter index lesion (mm), median (IQR)	12 (10–16)
Maximum percentage of cancer (%), median (IQR)	59 (36–80)
Overall no. of cores taken, median (IQR)	16 (14–19)
Overall no. of positive cores, median (IQR)	6 (4–8)
No. of TB cores in index lesion, median (IQR)	4 (3–5)
No. of positive TB cores in index lesion, median (IQR)	3 (2–4)
Index lesion ISUP Grade Group, *n*(%)	
0	83 (11)
1	167 (22)
2	278 (37)
3	117 (16)
4	80 (11)
5	28 (3.7)
No. of TB cores in secondary lesion, median (IQR)	3 (2–4)
No. of positive TB cores in secondary lesion, median (IQR)	1 (0–2)
Secondary lesion ISUP Grade Group, *n*(%)	
0	65 (36)
1	43 (24)
2	51 (28)
3	11 (6.1)
4	8 (4.4)
5	3 (1.7)
No. of ipsilateral SB cores, median (IQR)	6 (4–6)
No. of positive ipsilateral SB cores, median (IQR)	2 (0–3)
ISUP Grade Group at ipsilateral SB, *n* (%)	
0	199 (26)
1	177 (24)
2	220 (29)
3	81 (11)
4	63 (8.4)
5	13 (1.7)
ISUP Grade Group at biopsy, *n*(%)	
1	164 (22)
2	328 (44)
3	122 (16)
4	108 (14)
5	31 (4.1)

Table 1 (continued)

Parameter	Total ($n=753$)
ISUP Grade Group at radical prostatectomy, *n*(%)	
1	90 (12)
2	392 (52)
3	174 (23)
4	60 (8)
5	37 (4.9)
Pathological stage, *n*(%)	
pT2	468 (62)
pT3a-b	283 (38)
pT4	2 (0.3)

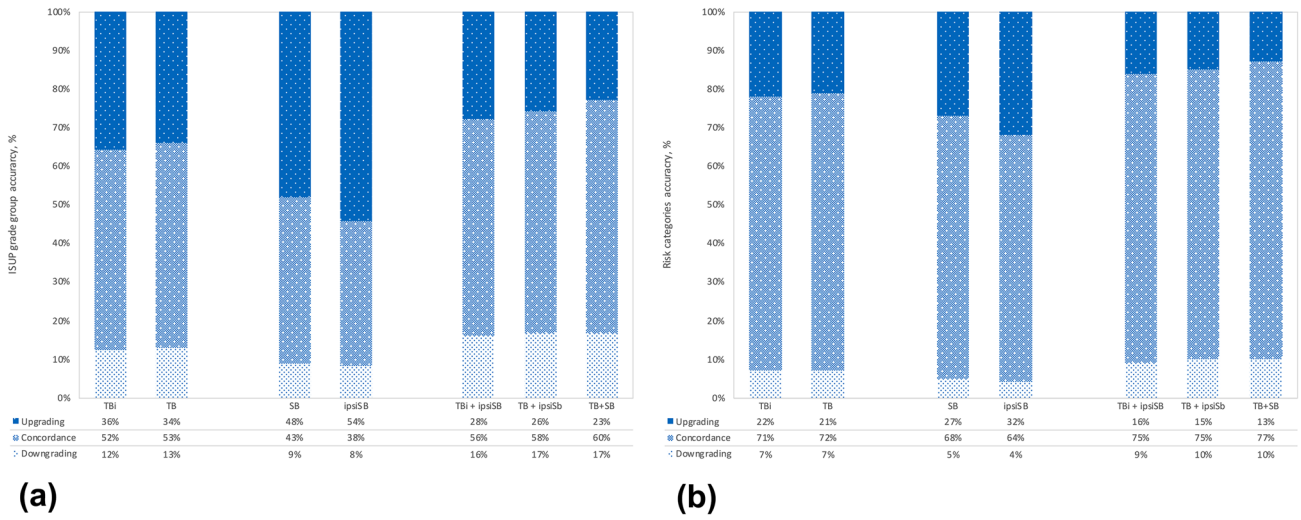

Fig. 1 Distribution of **a** ISUP grade group and **b** risk categories accuracies according to biopsy methods. *ISUP* International Society of Urological Pathology

(24–47%, 30–39%, 7–21% for systematic biopsy, MRI-targeted biopsy and both, respectively) rates, [3, 24–27]. The results of the present study confirm that the combination of MRI-targeted and systematic biopsies is the most accurate method and should be used in the current practice. In its most recent version, the EAU guidelines recommend this biopsy method for biopsy-naïve patients to reduce the risk of missing PCa foci [1].

Spatial distribution of cores in systematic template has been recently evaluated and introduced the concept of "penumbra", namely the biopsy cores taken in the area surrounding the MRI lesion [12, 13]. In a study of 971 men, Raman et al. evaluated 3-dimensional spatial distribution of 16,459 biopsy cores and shown that MRI-targeted and perilesional biopsies taken within a circumferential area of 2 cm detected 98% of csPCa with 3.7 fewer biopsy cores per patient compared to combined method [12]. More specifically, Brisbane et al. evaluated the location of 30,191 biopsy cores in 2048 men at 2 centers using elastic fusion and found that 90% of biopsy cores containing csPCa were located in a circumferential area of 1 cm although depending on MRI grading score [13]. These studies confirm the importance of penumbra sampling combined with MRI-targeted biopsy, compensating MRI-related issues (i.e., suboptimal images quality and misinterpretation depending on radiologist expertise), targeting errors (i.e., mismatch during images fusion, needle deflecting and operator expertise) or intrinsic characteristics of the tumor (i.e., constant underestimation of true tumor volume and intralesional tumor heterogeneity) [28]. Moreover, Bryk et al. described the importance of ipsilateral systematic biopsy to improve csPCa detection whereas contralateral sampling was at best associated with a limited added value [11]. Based on these observations, we previously conducted a study on 134 men, evaluating the risk of upgrading after biopsies taken in index MRI lesion and within a circumferential area of 1 cm [14]. We found that upgrading rate was relatively similar to the combination of systematic and MRI-targeted biopsies (23% vs 19%,

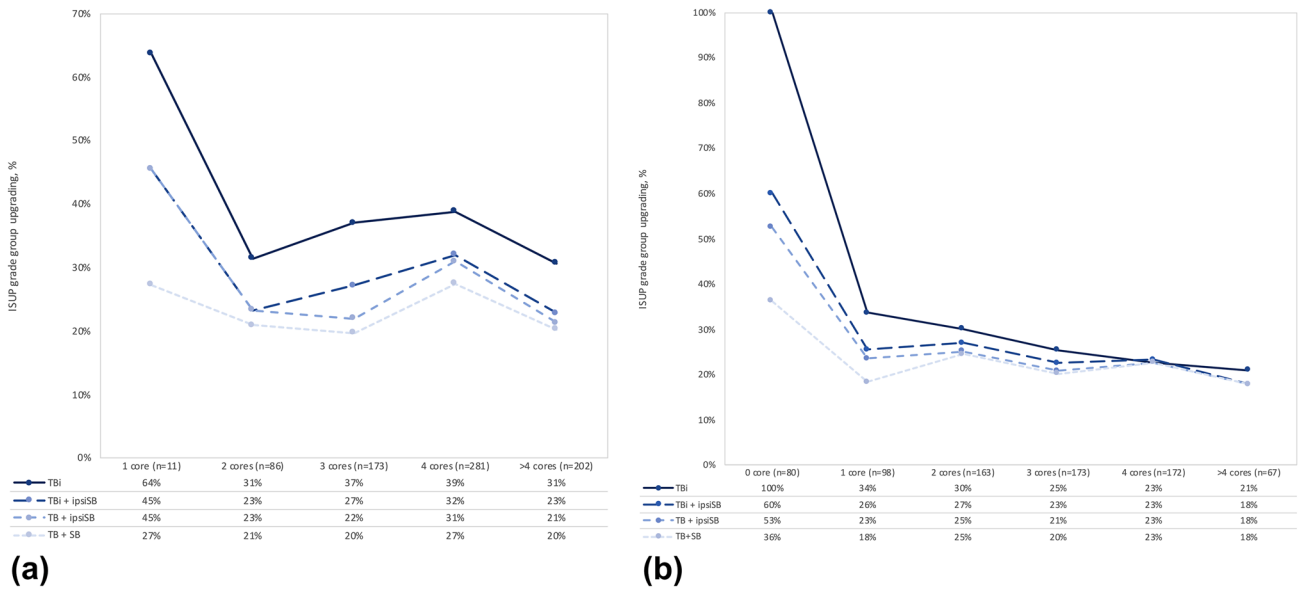

Fig. 2 Upgrading rate according to the number of **a** MRI-targeted biopsy cores and **b** positive MRI-targeted biopsy cores in the index MRI lesion. *MRI* magnetic resonance imaging

$p = 0.2$). To a certain extent, these results concur with those described in the present study. Indeed, a parallel can be drawn with ipsilateral systematic biopsy cores which contribute to the improvement of upgrading rate when combined with MRI-targeted biopsy, underlying the importance of focal and regional saturation of the MRI area. Therefore, we would argue in favor of less contralateral systematic biopsy sampling.

The optimal number of biopsy cores that need to be taken remains unclear. Focusing on csPCa detection, an average number of 3–5 MRI-targeted biopsy cores seems necessary to reach adequate detection rate [8, 9]. At multivariable analysis, we found that one of the independent predictive factors of upgrading using MRI-targeted and ipsilateral systematic biopsies method was the number of positive MRI-targeted biopsy cores contrary to the total number of cores taken. Of note, we did not observe major differences in term of upgrading rate from 1 to 4 positive biopsy cores (range of 21–25%). The discrepancy between the number of positive cores and the total number of cores taken reflects the variability of efficiency among centers when performing MRI-targeted biopsy with an overall upgrading rate ranging from 12 to 41%. With a positive MRI-targeted biopsy ratio (i.e., number of positive cores/total number of cores) ranging from 53 to 76%, clear recommendations regarding the optimal number of cores that need to be taken for each MRI lesion cannot be drawn [28]. Calio et al. evaluated whether saturation of index MRI lesion, defined as biopsy cores taken at 6 mm intervals along the long axis, would decrease the risk of upgrading compared with patients diagnosed by two biopsy cores [15]. They demonstrated that saturation biopsy (median number of cores 4 vs 2, $p < 0.001$) was associated with a significant lower rate of upgrading compared to control group (7% vs 18%, $p = 0.02$). To understand such a result, the same authors shown that increased number of MRI-targeted biopsy cores focused in the central and peripheral zones of index MRI lesion provide observable tumor heterogeneity in up to 58% of cases [29].

Surprisingly, we observed a marked discrepancy between clinical and pathological cancer staging. Indeed, upstaging occurred, respectively in 100% of patients initially classified as cT1 (i.e., 347/518, 135/518, 35/518, and 1/518 with pT2, pT3a, pT3b, and pT4, respectively), 43% of the cT2 (i.e., 71/212, 20/212, and 1/212 with pT3a, pT3b, and pT4, respectively) and 0% of the cT3. These results illustrate the well-known impact on PCa risk stratification when cancer staging only refers to DRE findings as recommended by current guidelines [1, 30]. Therefore, the use of MRI information has been increasingly evaluated. Soeterik et al. showed that MRI outperformed DRE with regard to cancer staging mainly due to superior detection of extra-prostatic extension disease. However, MRI-based staging was associated with a risk of upstaging in one-third of the patients [30]. More recently, an alternative MRI-based staging using PI-RADS score has been described and required external validation [31].

We found that radiological expertise defined according to ESUR/ESUI consensus statement was the second independent predictive factor of upgrading using MRI-targeted and ipsilateral systematic biopsies method. This finding is in line with the previous studies showing that MRI reporting and diagnostic accuracy varied across radiologists with

varying experience [32, 33]. A number of hypotheses might explain such result including undescribed tumor foci, PI-RADS score misclassification, inaccuracy of tumor volume measurement and delineation before MRI-targeted biopsy. It is therefore important to stress that biopsy process depends closely on the quality of MRI scans as well as the combined experience of the radiologist, urologist and pathologist [34].

We acknowledge the retrospective nature of the present analysis can introduce a selection bias. Although all centers adhered to the guidelines and terminology in current practice, the absence of central reviewing leads to consequent heterogeneity in MRI reporting and pathological analysis due to the implication of multiple physicians with different spectrum of expertise. Furthermore, although this reflects current real-life clinical practice, MRI and pathological analysis were not read blindly to the clinical characteristics of the patients and disease. Nonetheless, all the MRI was interpreted by dedicated genitourinary radiologist and analyzed using PI-RADS v2 or 2.1 which provide substantial inter-reader agreement in interpretation [35]. Dedicated MRI-targeted biopsies were all performed using KOELIS system, reducing subjectivity and variability in biopsy cores analysis compared to cognitive approach. Finally, the absence of predefined biopsy template which may be influenced by physician's experience and the disease itself (e.g., location, size, and PI-RADS score of the lesion) and the use of transrectal approach may introduced another selection bias and limit extrapolation of our results.

Conclusion

Combination of MRI-targeted and ipsilateral systematic biopsies allowed an accurate definition of ISUP grade group according to final pathology and appears to be an interesting alternative as compared with standard method, reducing total number of biopsy cores needed. Furthermore, adequate MRI-targeted biopsy sampling by obtaining a sufficient number of positive cores is required to enhance biopsy accuracy, improve preoperative planning, and patient counselling. The clinical impact of reducing or modifying the current biopsy templates requires validation with further prospective studies.

IQR interquartile range, *ISUP* international society of urological pathology, *PI-RADS* prostate imaging reporting and data system, *PSA* prostatic-specific antigen, *SB* systematic biopsy, *TB* targeted biopsy, *PCa* prostate cancer, *MRI* magnetic resonance imaging, *RP* radical prostatectomy.

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Author contributions RD: project development, data collection, data analysis, manuscript writing. SA: project development, supervision, manuscript editing. AP, TR: supervision. J-BR, EL, VL, GC, VB, RM, GS, OW, DB, AF, TAN, Georges Fournier, Gaelle Fiard, GP: data collection.

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Data availability Data are available upon request to the corresponding author.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Research involving human participants and/or animals This is a retrospective study. For this type of study formal consent is not required.

References

1. Mottet N, van den Bergh RCN, Briers E et al (2021) EAU-EANM-ESTRO-ESUR-SIOG guidelines on prostate cancer—2020 update. Part 1: screening, diagnosis, and local treatment with curative intent. Eur Urol 79:243–262. https://doi.org/10.1016/j.eururo.2020.09.042
2. Hanna N, Wszolek MF, Mojtahed A et al (2019) Multiparametric magnetic resonance imaging-ultrasound fusion biopsy improves but does not replace standard template biopsy for the detection of prostate cancer. J Urol 202:944–951. https://doi.org/10.1097/JU.0000000000000359
3. Diamand R, Oderda M, Al Hajj Obeid W et al (2019) A multicentric study on accurate grading of prostate cancer with systematic and MRI/US fusion targeted biopsies: comparison with final histopathology after radical prostatectomy. World J Urol 37:2109–2117. https://doi.org/10.1007/s00345-019-02634-9
4. Drost F-JH, Osses DF, Nieboer D et al (2019) Prostate MRI, with or without MRI-targeted biopsy, and systematic biopsy for detecting prostate cancer. Cochrane Database Syst Rev. https://doi.org/10.1002/14651858.CD012663.pub2
5. Loeb S, Vellekoop A, Ahmed HU et al (2013) Systematic review of complications of prostate biopsy. Eur Urol 64:876–892. https://doi.org/10.1016/j.eururo.2013.05.049
6. Weiner AB, Manjunath A, Kirsh GM et al (2020) The cost of prostate biopsies and their complications: a summary of data on all medicare fee-for-service patients over 2 years. Urol Pract 7:145–151. https://doi.org/10.1097/UPJ.0000000000000072
7. Mottet N, Cornford P, van den Bergh RCN, Briers E, De Santis M, Fanti S, Gillessen S, Grummet J, Henry AM, Lam TB, Mason MD, van der Kwast TH, van der Poel HG, Rouvière O, Schoots IG, Tilki TW D (2020) EAU guidelines: prostate cancer 2020. In: Eur Urol. https://uroweb.org/guideline/prostate-cancer/
8. Leyh-Bannurah S-R, Kachanov M, Beyersdorff D et al (2020) Minimum magnetic resonance imaging-ultrasound fusion targeted biopsy cores needed for prostate cancer detection: multivariable retrospective, lesion based analyses of patients treated with radical prostatectomy. J Urol 203:299–303. https://doi.org/10.1097/JU.0000000000000527
9. Lu AJ, Syed JS, Ghabili K et al (2019) Role of core number and location in targeted magnetic resonance imaging-ultrasound fusion prostate biopsy. Eur Urol 76:14–17. https://doi.org/10.1016/j.eururo.2019.04.008
10. Tu X, Lin T, Cai D et al (2020) The optimal core number and site for MRI-targeted biopsy of prostate? A systematic review and

pooled analysis. Minerva Urol Nefrol. https://doi.org/10.23736/S0393-2249.20.03639-5
11. Bryk DJ, Llukani E, Taneja SS et al (2017) The role of ipsilateral and contralateral transrectal ultrasound-guided systematic prostate biopsy in men with unilateral magnetic resonance imaging lesion undergoing magnetic resonance imaging-ultrasound fusion-targeted prostate biopsy. Urology 102:178–182. https://doi.org/10.1016/j.urology.2016.11.017
12. Raman AG, Sarma KV, Raman SS et al (2021) Optimizing spatial biopsy sampling for the detection of prostate cancer. J Urol 206:595–603. https://doi.org/10.1097/JU.0000000000001832
13. Brisbane WG, Priester AM, Ballon J et al (2022) Targeted prostate biopsy: umbra, penumbra, and value of perilesional sampling. Eur Urol. https://doi.org/10.1016/j.eururo.2022.01.008
14. Diamand R, Hollans M, Lefebvre Y et al (2022) The role of perilesional and multiparametric resonance imaging-targeted biopsies to reduce the risk of upgrading at radical prostatectomy pathology: a retrospective monocentric study. Urol Oncol Semin Orig Investig 40:192.e11-192.e17. https://doi.org/10.1016/j.urolonc.2022.01.011
15. Calio BP, Sidana A, Sugano D et al (2018) Risk of upgrading from prostate biopsy to radical prostatectomy pathology—does saturation biopsy of index lesion during multiparametric magnetic resonance imaging-transrectal ultrasound fusion biopsy help? J Urol 199:976–982. https://doi.org/10.1016/j.juro.2017.10.048
16. Ploussard G, Beauval J-B, Renard-Penna R et al (2020) Assessment of the minimal targeted biopsy core number per MRI lesion for improving prostate cancer grading prediction. J Clin Med 9:225. https://doi.org/10.3390/jcm9010225
17. Barentsz JO, Richenberg J, Clements R et al (2012) ESUR prostate MR guidelines 2012. Eur Radiol 22:746–757. https://doi.org/10.1007/s00330-011-2377-y
18. Weinreb JC, Barentsz JO, Choyke PL et al (2016) PI-RADS prostate imaging—reporting and data system: 2015, version 2. Eur Urol 69:16–40. https://doi.org/10.1016/j.eururo.2015.08.052
19. Turkbey B, Rosenkrantz AB, Haider MA et al (2019) Prostate imaging reporting and data system version 2.1: 2019 update of prostate imaging reporting and data system version 2. Eur Urol 76:340–351. https://doi.org/10.1016/j.eururo.2019.02.033
20. de Rooij M, Israël B, Tummers M et al (2020) ESUR/ESUI consensus statements on multi-parametric MRI for the detection of clinically significant prostate cancer: quality requirements for image acquisition, interpretation and radiologists' training. Eur Radiol 30:5404–5416. https://doi.org/10.1007/s00330-020-06929-z
21. Epstein JI, Egevad L, Amin MB et al (2015) The 2014 International Society of Urological Pathology (ISUP) consensus conference on Gleason grading of prostatic Carcinoma. Am J Surg Pathol 40:1. https://doi.org/10.1097/PAS.0000000000000530
22. Giannarini G, Crestani A, Rossanese M et al (2020) Multiparametric magnetic resonance imaging-targeted prostate biopsy: a plea for a change in terminology, and beyond. Eur Urol Oncol 3:395–396. https://doi.org/10.1016/j.euo.2018.12.003
23. Goel S, Shoag JE, Gross MD et al (2020) Concordance between biopsy and radical prostatectomy pathology in the era of targeted biopsy: a systematic review and meta-analysis. Eur Urol Oncol 3:10–20. https://doi.org/10.1016/j.euo.2019.08.001
24. Borkowetz A, Platzek I, Toma M et al (2016) Direct comparison of multiparametric magnetic resonance imaging (MRI) results with final histopathology in patients with proven prostate cancer in MRI/ultrasonography-fusion biopsy. BJU Int 118:213–220. https://doi.org/10.1111/bju.13461
25. Andras I, Cata ED, Serban A et al (2021) Combined systematic and MRI-US fusion prostate biopsy has the highest grading accuracy when compared to final pathology. Medicina (B Aires) 57:519. https://doi.org/10.3390/medicina57060519
26. Ryan J, Broe MP, Moran D et al (2021) Prostate cancer detection with magnetic resonance imaging (MRI)/cognitive fusion biopsy: comparing standard and targeted prostate biopsy with final prostatectomy histology. Can Urol Assoc J. https://doi.org/10.5489/cuaj.6951
27. Rapisarda S, Bada M, Crocetto F et al (2020) The role of multiparametric resonance and biopsy in prostate cancer detection: comparison with definitive histological report after laparoscopic/robotic radical prostatectomy. Abdom Radiol 45:4178–4184. https://doi.org/10.1007/s00261-020-02798-8
28. Gold SA, Hale GR, Bloom JB et al (2019) Follow-up of negative MRI-targeted prostate biopsies: when are we missing cancer? World J Urol 37:235–241. https://doi.org/10.1007/s00345-018-2337-0
29. Calio BP, Deshmukh S, Mitchell D et al (2019) Spatial distribution of biopsy cores and the detection of intra-lesion pathologic heterogeneity. Ther Adv Urol 11:175628721984248. https://doi.org/10.1177/1756287219842485
30. Soeterik TFW, van Melick HH, Dijksman LM et al (2021) Multiparametric magnetic resonance imaging should be preferred over digital rectal examination for prostate cancer local staging and disease risk classification. Urology 147:205–212. https://doi.org/10.1016/j.urology.2020.08.089
31. Baboudjian M, Gondran-Tellier B, Touzani A et al (2022) Magnetic resonance imaging–based T-staging to predict biochemical recurrence after radical prostatectomy: a step towards the iTNM classification. Eur Urol Oncol. https://doi.org/10.1016/j.euo.2022.09.005
32. Sonn GA, Fan RE, Ghanouni P et al (2019) Prostate magnetic resonance imaging interpretation varies substantially across radiologists. Eur Urol Focus 5:592–599. https://doi.org/10.1016/j.euf.2017.11.010
33. Kasabwala K, Patel N, Cricco-Lizza E et al (2019) The learning curve for magnetic resonance imaging/ultrasound fusion-guided prostate biopsy. Eur Urol Oncol 2:135–140. https://doi.org/10.1016/j.euo.2018.07.005
34. Giganti F, Allen C, Emberton M et al (2020) Prostate Imaging Quality (PI-QUAL): a new quality control scoring system for multiparametric magnetic resonance imaging of the prostate from the PRECISION trial. Eur Urol Oncol 3:615–619. https://doi.org/10.1016/j.euo.2020.06.007
35. Park KJ, Choi SH, Lee JS et al (2020) Interreader agreement with prostate imaging reporting and data system version 2 for prostate cancer detection: a systematic review and meta-analysis. J Urol 204:661–670. https://doi.org/10.1097/JU.0000000000001200