Review Article

Magnetic Resonance Guided Prostate Biopsies: Current Perspectives

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Chettinad Health City Medical Journal 2020; 9(3): 161 - 170

DOI: https://doi.org/10.36503/chcmj9(3)-05

Abstract

Magnetic resonance image-guided prostate biopsy (MRGB) is rapidly becoming the standard pathway of prostate cancer detection. MRGB increases detection of clinically significant prostate cancer while minimizing over-detection of indolent prostate cancers. MRGB includes various techniques and, while there are only a few randomized studies with head-to-head comparison, economic considerations and available resources will contribute to choosing the optimum technique. In this narrative review, we discuss the current perspectives of MRGB in terms of detection rate of various techniques, current controversies in obtaining the cores, management of previous negative MRGB and recent advancements in the technique.

Keywords: magnetic resonance imaging, image-guided biopsy, prostate cancer, diagnosis

Introduction

A systematic, 12-core, transrectal ultrasound-guided biopsy (TRUS-Bx) is the current standard technique of prostate cancer (PCa) detection in men with clinical suspicion based on abnormal digital rectal examination (DRE) and/or elevated serum prostate specific antigen (PSA).

The detection rate of PCa with a systematic biopsy (SB) is only around 30-40%.[1,2] Not all PCas is aggressive and a number of cancers detected by SB are clinically insignificant and do not require treatment. Further, SB under-detects clinically significant PCa (csPCa) which can potentially result in disease progression. Thus, there exists a need to identify tools that can help avoid unnecessary biopsies without missing csPCa. Among imaging techniques, magnetic resonance imaging (MRI) has provided the greatest promising for optimizing outcomes.[3]

The introduction of multiparametric MRI (mpMRI) opened a new alternative pathway of PCa diagnosis as it allows targeted biopsies (TB) in suspicious areas. Magnetic resonance image-guided biopsy (MRGB) is rapidly becoming the standard approach, endorsed by international guidelines. In this review, we will discuss the current evidence and controversies in clinical practices of MRGB followed by the management of prior negative MRGB and recent advances in MRGB.

Materials and methods

We performed a search of PubMed/Medline, Embase, Web of Science and Google Scholar databases for English literature to identify all the relevant studies using the following MeSH keywords: (magnetic resonance imaging OR MRI OR multiparametric MRI OR mpMRI) AND (cognitive fusion OR visual registration OR fusion biopsy OR MRI/TRUS fusion biopsy OR in-bore OR in-gantry OR targeted biopsy) AND (prostate cancer OR prostatic carcinoma OR prostate adenocarcinoma). The abstracts, full articles including systematic review and meta-analyses were reviewed for the relevant contents. Case reports, letters, short communications, editorials and articles in non-English language were excluded.

MRI pathway for prostate biopsy

Technical advancements in MRI technology and standardization and improvement in mpMRI have allowed better identification of abnormal lesions. Prebiopsy MRI has been shown to have a high negative predictive value (NPV) for detection of PCa. In the PROMIS study, the utility of mpMRI as triage was evaluated. The NPV for ruling out csPCa was 76% vs 63% for MRI and TRUS-Bx, respectively.[4] The authors showed that over a quarter of men could avoid a biopsy if they underwent mpMRI prior to biopsy. Further, biopsy guided by the MRI, targeted

biopsy (TB), would have resulted in 18% more detection of csPCa and 5% few clinically indolent PCa.

A TB core is expected to be more representative of the cancer pathology, expressed as Gleason score (GS), as the biopsy needle traverses the center of the lesion, when compared with a non-targeted core as in SB.[3] This raises a question of whether TB alone should be performed, without SB. A multicenter, randomized, non-inferiority trial, called the PRECISION study, recently addressed this issue.[5] In this landmark study, 500 biopsy naïve men with a suspicion of PCa were randomized to undergo a pre-biopsy mpMRI to identify lesions suspected to harbor PCa or proceed directly to SB. In the MRI group, only men with an abnormal MRI were biopsied using TB whereas men with MRI findings not suggestive of PCa were not offered a biopsy. The proportion of men with csPCa defined as Gleason ≥ 3+4 was the primary outcome measure. The authors found 38% csPCa in MRI-TB as compared to 26% in SB group. Men in the MRI-TB group had 12% more csPCa (38% vs 26%, p=0.005) and 13% fewer indolent PCa than SB (9% vs 22%, p<0.001). Importantly, 28% of men avoided prostate biopsy as they had negative mpMRI. They concluded that the MRI-pathway reduces the number of men needing a prostate biopsy and its associated complications.

In a recent systematic review and meta-analysis of 9 RCTs (2908 men) comparing the MRI-pathway versus the systematic TRUS-Bx pathway, the MRI-pathway detected more csPCa than the TRUS-Bx pathway.[6] The relative detection rate of csPCa was 1.45 [95% CI 1.09–1.92] for all patients. For biopsy naïve and prior negative biopsy men, it was 1.42 [95% CI 1.02–1.97] and 1.60 [95% CI 1.01–2.54], respectively.

These studies support the superiority of MRI-pathway than the TRUS-Bx pathway which has led their incorporation in both biopsy naïve and repeat biopsy settings in the current international guidelines of PCa detection.[7,8]

Multiparametric MRI of the prostate- the current standard

mpMRI of the prostate incorporating T2W image (T2WI), diffusion-weighted imaging (DWI) and dynamic contrast-enhanced (DCE) protocol represents the most comprehensive diagnostic approach to PCa. One major step in the improvement of quality assurance in mpMRI is the PI-RADSv2 (Prostate Imaging and Reporting Archiving Data System) reporting system for scoring lesions.[9] The performance of PI-RADSv2 has been validated in various studies. Kasel-Siert et al.[10] showed the improved diagnostic performance in terms of area under the ROC (Receiver Operating Characteristics) Curve of PI-RADSv2 than PI-RADSv1 in both experienced (Area under curve (AUC) 0.83 vs 0.79) and inexperienced reader (AUC 0.83 vs 0.70). Additionally, the inter-reader agreement was higher in PI-RADSv2.

MRGB techniques

Data gathered from MRI images has to be used while performing a biopsy. Biopsies are usually performed using ultrasound guidance and MRI images have to be 'fused' with real-time ultrasound images. The three common methods in which MRGB is performed are cognitive fusion targeted biopsy (COG-TB), MRI/TRUS fusion targeted biopsy (FUS-TB) and MRI 'in-bore' or 'in-gantry' targeted biopsy (MRI-IB) (Table 1). The MRGB differ in their techniques and each has its advantages and disadvantages based on the availability of the equipment, operator experience and cost.[3]

Parameters	COG-TB	MRI-IB	FUS-TB
Duration of procedure[11,12]	< 30 minutes to perform SB + TB	Range 19 to 68 minutes	< 30 minutes to perform SB + TB
Spatial resolution	Low	High	High
Realtime feedback during TB	No	High	High
Accuracy of needle positioning	Less precise	Most precise	More precise
Effectiveness in targeting small lesions (lesions <10 mm)	Low and operator dependent	High	High
Learning curve[13,14]	Steep learning curve	Around 10 procedures in terms of biopsy time and number of cores obtained	Around 98 cases in terms of targeted biopsy accuracy

Table 1: Comparison of three techniques of MRGB

MRI cognitive biopsy (COG-TB)

Technique

In COG-TB, the operator reviews the MRI images to identify the suspicious lesions corresponding to the fiducial landmarks like prostate zones and distance from the bladder neck or apex. By extrapolating the MRI findings, the visual registration is then transformed into the real-time TRUS images for targeting the suspicious areas.[15]

PCa detection rate

In a biopsy naïve setting, Park et al. randomized men with rising PSA between COG-TB vs standard TRUS-Bx and found higher PCa detection rate in COG-TB (30% vs 10%).[16] COG-TB also detected 16% more csPCa than the standard SB. About 13% clinically insignificant PCa could have been avoided with the application of TB alone.[17] With experienced hands, COG-TB resulted in 82% accuracy of hitting the target lesion. However, the more anterior tumors were less likely to be targeted.[18]

Advantages

COG-TB is a relatively simple technique that allows performing targeted biopsies without additional software. The availability of TRUS and knowledge of anatomy on MRI is all that is required to enable targeted biopsies. This makes the COG-TB a less expensive option in low-cost settings.

Limitations

COG-TB is more prone to human error while extrapolating the MRI findings with the real-time TRUS image. The mis-registration results from incorrect judgement of the lesion location. This is particularly common with inexperienced operators or failure to review the MRI images by the operator himself.[15] However, the consensus statement of the American Urological Association and Society of Abdominal Radiology (AUA-SAR) recommend the adequacy of cognitive biopsies in resource-poor settings when skilled operators are available.[19]

MRI "in-gantry" / "in-bore biopsy" (MRI-IB)

Technique

In MRI-IB, the operator analyses the previously obtained prostate MRI findings for the target lesion. The images are then used to perform a biopsy during a second MRI session. DynaTRIM (Invivo Corp, Gainesville, FL, USA) is the most common platform used to obtain MRI-IB (Figure 1). It consists of a baseplate to be fitted on the MRI table and a clamp stand to which the needle sleeve is attached. The needle sleeve acts both as fiducial and a guide for advancing the needle to the target lesion. The patient is placed in prone position within the gantry and the needle sleeve is advanced into the rectum. T2W images are obtained in three planes (axial, coronal and sagittal) and the position of the needle sleeve, the prostate gland and the target lesions are directly visualized. The images are transferred to a special software, DynaCAD, which guides targeting the lesion with needle sleeve as a fiducial. Typically, two or three cores are taken per target lesion.[15]

PCa detection rate

The MRI-IB cores detected more PCa than the standard 12-core SB (85% vs 79%).[20] By targeting precisely, the detection rate of csPCa was 81-95% even with the fewer cores.[12] MRI-IB cores were also found to be highly representative of the final GS. Hambrock et al. found a concordance rate of 88% in GS between the targeted cores and the final prostatectomy specimen.[21] The number of cores that needs to be taken in MRI-IB was addressed by Schimmöller et al.[22] In a retrospective analysis of 1545 biopsy cores in 290 men with MRI-IB, the authors found obtaining only one core per lesion did not affect the final GS when compared to two cores. The GS up-gradation to csPCa (GS ≥4+3) in the final histopathology was present in only 2.3% of single-core MRI-IB.[22]

Advantages

MRI-IB has a low chance of missing the target as the biopsy technique is monitored real-time "in-gantry". This also eliminates the errors of misregistration associated with other MRGB. As it precisely biopsies the target lesion, it requires only a few cores and is associated with lower complications.

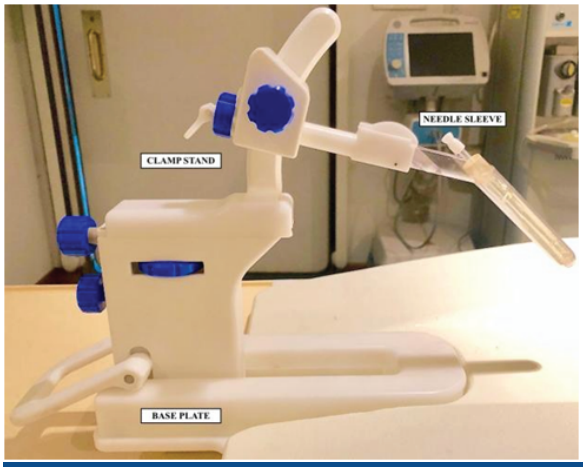

Figure 1: DynaTrim platform used during MRI in-bore biopsy. The baseplate is mounted on the table once the patient is placed in prone position and the needle sleeve is advanced into the rectum.

Limitations

MRI-IB requires a skilled operator to interpret and orient the real-time advancement of biopsy needle within the limited confinement of the "in-gantry" setup. In contrast to the other MRGB, MRI-IB lacks the concomitant SB. MRI-IB is more uncomfortable because of prone position during the entire procedure.[15]

MRI/TRUS fusion biopsy (FUS-TB)

Technique

MRI/TRUS fusion biopsy (FUS-TB) combines the advantages of both the MRI and ultrasonogram (USG). Various platforms are currently available to fuse the MR images with real-time TRUS images (Table 2 and Figure 2). The main steps in the FUS-TB are segmentation of the prostate and tumor on the mpMRI, prostate volume acquisition and segmentation on TRUS, the fusion of MRI and TRUS images and performing biopsies using probe tracking.[15]

PCa detection rate

Panebianco et al. randomized 1140 biopsy naïve men with PSA > 4 ng/ml into TRUS-Bx and FUS-TB+SB. They found a higher detection of csPCa in the fusion group (410/570 men) than TRUS-guided biopsy (210/570 men).[23]

Cool et al. found FUS-TB detected 14% csPCa in the repeat biopsy setting following atypical small acinar proliferation. This suggests that targeting corrects the systematic error of missing midline, anterior, apical and extreme basal tumors, more often than the random error of missing a peripheral zone tumor.[24] In a prospectively maintained database of 1003 men with both biopsy naïve and repeat biopsy settings, Siddiqui et al. showed FUS-TB detected 30% more csPCa and 17% fewer clinically low-risk PCa.[25]

Advantages

The main advantages of FUS-TB are its exploitation of the high sensitivity and specificity of the MRI in detecting the suspicious lesion and incorporating TRUS to enable ease of performing a targeted biopsy. Unlike other MRGB, FUS-TB allows urologists to quickly adopt the MRGB in their clinical practice.[26]

Limitations

One of the major limitations of FUS-TB is the initial high cost for the software platform. FUS-TB also associated with mis-registration resulting from the compression by the TRUS probe which deforms the shape of the prostate and the region of interest (ROI).[15] Also, the subtle differences in the prostate outlines between the MRI and TRUS images can result in a deformed fused image of the prostate.[27]

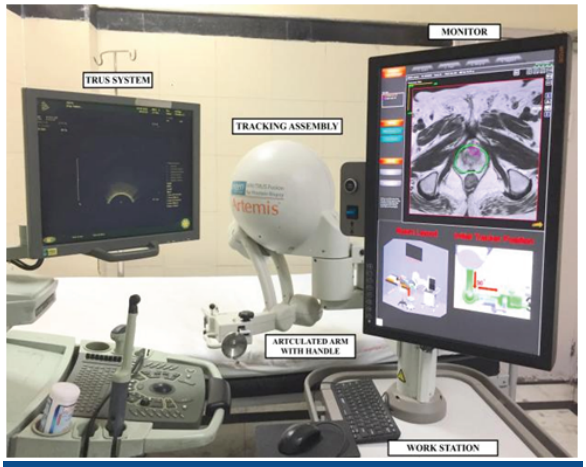

Figure 2: Photograph showing MRI/TRUS Eigen-Artemis fusion biopsy platform with transrectal ultrasound system (left side) and fusion device with monitor and the tracking assembly (right side)

Platforms	Year of FDA approval	Fusion method	Route of biopsy
Philips/Uronav	2005	Elastic	Transrectal
Eigen/Artemis	2008	Elastic	Transrectal
Koelis/Urostation	2010	Elastic	Transrectal/transperineal
Hitachi/Hi-RVS	2010	Rigid	Transrectal/transperineal
Geoscan/BioJet	2012	Elastic	Transrectal/transperineal
Smart Target	2017	Rigid	Transperineal
BK Fusion	2018	Rigid	Transrectal/transperineal
Canon/Apilo	2019	Rigid	Transrectal

Table 2: FDA approved MRI/TRUS fusion biopsy platforms

Comparison of the different techniques of MRGB

Studies on COG-TB vs FUS-TB

The literature comparing the COG-TB versus FUS-TB shows mixed results. The PROFUS trial showed the FUS-TB and COG-TB did not differ significantly in terms of csPCa detection (20.3% vs 15.1%, p=0.052). However, FUB-TB outperformed in targeting smaller lesions. Of note, the learning curve of FUS-TB was shorter than COG-TB.[28]

Later Lee et al. reported the differences between FUS-TB and COG-TB to be –1.4% (p=0.6) and 3.5% (p=0.2) for the detection of high grade and any PCa, respectively. FUS-TB detected tumors in the transition zone that are difficult to visually target in COG-TB.[29] In contrast, Oberlin et al. found a higher detection rate of PCa with the FUS-TB than the COG-TB (48.1% vs 34.65, p=0.04).[30] The recent PICTURE trial showed that the cognitive biopsy missed 13.6% of PCa detected by the fusion biopsy. Conversely, the fusion biopsy missed 10.8% of PCa detected by the cognitive biopsy.[31]

Studies on MRI-IB vs FUS-TB

On comparing the MRI-IB and FUS-TB in men with prior negative biopsies, Arsov et al. did not find any difference between the two techniques in terms of csPCa (29% vs 32%) and highest percentage of tumor involvement per core (48% vs 42%).[32]

Studies on COG-TB vs MRI-IB

In a retrospective analysis, the COG-TB detected 50% PCa as compared to 65% PCa with MRI-IB. Stratified by the MRI lesion volume, MRI-IB detected significantly more PCa in lesions <1.5 ml. Above 1.5 ml both the techniques were comparable.[33]

Head-to-head comparison of the three MRGB techniques

In a study by Mouraviev et al. the three techniques of MRGB were compared in 32 men. The PCa detection rate was significantly higher in FUS-TB than the COG-TB (46.2% vs 33.3%, p=0.005). The MRI-IB detected (80%) more PCa than the FUS-TB. However, the study is limited by the small sample size and majority of the men in the"in-bore" biopsy group had a previously diagnosed low-risk prostate cancer on TRUS-guided SB.[34] In a systematic review, the three techniques of MRGB did not differ significantly for csPCa detection. The MRI-IB outperformed COG-TB for overall PCa detection (P=0.02). However, neither MRI-IB compared with FUS-TB (P=0.13) nor COG-TB compared with FUS-TB (P=0.11) had a significant advantage in the detection of PCa.[35] Similarly, in men with prior negative SB and persistent suspicion of PCa, the multicentre FUTURE trial showed that the three techniques did not differ significantly in the detection of any PCa (FUS-TB 49%, COG-TB 44%, MRI-IB 55%, P = 0.4) as well as csPCa (FUS-TB 34%, COG-TB 33%, MRI-IB 33%, P > 0.9).[36]

Current evidences of performing targeted alone or combined biopsies in MRGB

Proponents of TB alone

Proponents of performing MRI targeted biopsies (MRI-TB) alone in MRI positive patients argue that TB maintains or improves the detection of csPCa with fewer cores.[5,23] In addition, it allows men with low risk for PCa to avoid unnecessary biopsies and the associated overtreatment. This is evaluated in a recent review, of 14,709 men who received MRI-TB and/or SB. The csPCa was detected more with MRI-TB than SB (detection ratio [DR] 1.16, P<0.0001). MRI-TB detected fewer clinically insignificant PCa than SB (DR 0.66, P<0.0001) and had a greater proportion of cores positive for PCa (relative risk 3.17, P<0.0001). The authors discuss that their data allow clinicians and patients to make informed decisions on MRI-TB as a replacement test for or an additional test to SB.[37]

Proponents of combined biopsy

The additive value of SB or TB by combining both in the detection of csPCa was shown in MRI-FIRST trial. The TB alone approach missed 5.2% of csPCa detected by the SB. Conversely, performing SB alone missed 7.6% of csPCa detected in the TB.[38] Similarly, Kaushal et al. in their prospective study, showed 8.3% of PCa was exclusively detected on SB cores but missed by the TB while another 8.3% of PCa was exclusively detected on TB cores but missed by SB.[39] In the consensus statement by the AUA-SAR, the authors suggested not to defer concurrent SB with TB until sufficient expertise, accuracy, and supporting evidence has been obtained with targeted biopsies.[19] In a recent study involving more than 2000 men, a combined biopsy detected a more PCa as compared to SB or TB alone (62.4% vs 52.5% vs 51.5%). In their data, the omission of SB would have missed 8.8% of csPCa. The combined biopsy was associated with the lowest rate of grade group upgrading between biopsy cores and the wholemount histopathological analysis.[40]

What do the current guidelines say?

Guidelines on MRGB in biopsy naïve setting

The recent international guidelines recommend mpMRI prior to biopsy for all men, without previous history of biopsy, under consideration for prostate biopsy.[7,8] The EAU guideline stated the

addition of TB to SB increases the number of csPCa by 20%. Omitting SB would miss 16% csPCa in biopsy-naïve patients and recommends combined targeted and systematic biopsy when mpMRI is positive (PIRADS ≥ 3).[7]

Guidelines on MRGB in repeat biopsy setting

In men with a negative previous biopsy who have a rising PSA and thus an indication for repeat biopsy, recent guidelines strongly recommend the use of mpMRI.[7,8] Patients with positive MRI (PIRADS >3) should undergo an image-targeted biopsy and FUS-TB or MRI-IB aid such targeting. COG-TB remains an alternative option if machine guided targeting is not available.[8]

While the European guidelines recommend performing a TB alone in patients with positive MRI and SB for MRI negative patients, the AUA-SAR note that TB alone, without SB, resulted in a number of missed cancers. Since the accuracy of TB also depends on experience, TB alone should be performed only when data from the centre are consistent with the published literature.[7,8]

PIRADS steering committee recommendations

A panel of experts from Europe and United States have recently shown the improved performance of PIRADSv2. In research and clinical practice, PIRADSv2 retained higher accuracy than systemic TRUS-Bx for PCa detection.[41] Subsequently, the consensus panel recommended performing 1) a high quality PIRADSv2 compliant mpMRI before prostate biopsy in men suspected to harbor clinically important disease. 2) A safety net of monitoring must be in place for men who decline immediate biopsy after mpMRI reveals a low likelihood of disease (i.e. PIRADS 1 or 2). This should include clinical (including DRE), laboratory (including PSA) and imaging monitoring as per local clinical practice. Importantly, the roles and responsibilities of the participants and the circumstances that should trigger reinvestigations should be clearly defined. Lastly, 3) for men proceeding to biopsy after mpMRI reveals intermediate or high likelihood of disease (i.e. PIRADS category 3 or higher), a combination of SB and TB should be performed in biopsy-naïve men whereas only TB are needed in men with persistent suspicion of PCa after prior negative systematic TRUS-Bx.[42]

Standards of Reporting for MRI-Targeted Biopsy Studies (START) of the Prostate Recommendations

In line with the Standards for Reporting of Diagnostic Accuracy (STARD) guidelines for reporting and reviewing studies on the accuracy of diagnostic medical tests, a similar reporting model "Standards of Reporting for MRI-Targeted Biopsy Studies (START) of the Prostate: Recommendations from an International Working Group" was proposed by Moore et al.[43] The authors introduced a 20-item "START checklist" that acts as a guide for reporting studies on MRI targeted prostate biopsies, specifying the details that should be included regarding the methodology, study population, conduct and reporting of the MRI, conduct of the biopsy procedures, and in the results and discussion sections.[43]

Follow-up protocol of patients with initial negative MRI guided TB

Patients with prior negative MRGB should be evaluated for possible sources of error. Firstly, PCa mimics such as focal hyperplasia, prostatitis, fibrosis, BPH nodules with a predominant stromal elements and recent prostate biopsy with intraprostatic hemorrhage can cause false-positive mpMRI. Other less common causes are previous prostate therapies and cystic or granulomatous prostatic lesions. Secondly, registration error especially during FUS-TB, needle deflection during the procedure and inexperienced operator leads to false-negative TB. Reviewing the pathological slides for PCa mimics and the needle tack (Figure 3) to rule out hitting "on" (false positive mpMRI) or "off" (false negative TB) the target lesion should be taken into consideration for further management of initial negative MRGB. PCa mimics and false positive mpMRI should be followed with continued PSA monitoring and repeat mpMRI and/or biopsy if clinically indicated. A repeat biopsy is also indicated if a reconstruction of the needle path shows that the biopsy missed the target.[44]

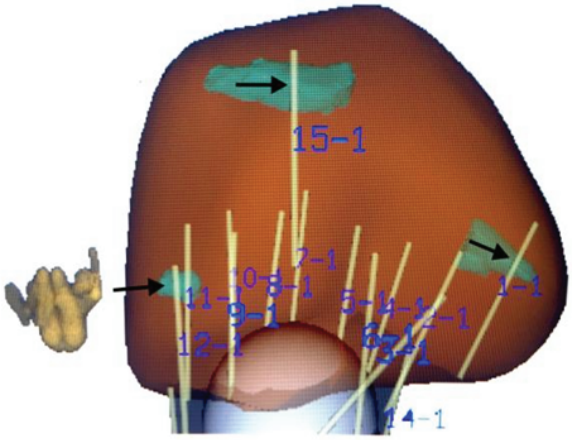

Figure 3: Review of biopsy tracks showing correct sampling (black arrow marks) of the three ROIs (green shaded areas)

Recent advances in MRGB

Transperineal-MRI guided biopsy (TP-MRGB)

The transperineal (TP) template prostate biopsies were traditionally done for men with multiple prior negative biopsies yet continued to have a high clinical suspicion of PCa. The concern for infection associated with the TRUS-Bx made the researches revisiting the TP biopsy. Further, few centers explored the utility of TP-MRGB under local anesthesia as an outpatient procedure.[45]

The transperineal FUS-TB was evaluated in 106 men and PCa was detected in 59% of men. The cancer detection per core rates was higher in transperineal FUS-TB cores than SB cores (25% vs 9%).[46] In a comparative study, TP saturation biopsies, transrectal FUS-TB and transperineal COG-TB detected 98.3%, 78.3% and 93.3% of csPCa, respectively. Of note, the transperineal COG-TB detected a higher csPCa of the anterior zone than transrectal FUS-TB (93.3% vs 25%, P=0.0001).[47]

Bi-parametric MRI protocol

Although mpMRI is the current standard reference of MRI in PCa detection, it has limitations in particular with the DCE sequences. Few researchers proposed a "bi-parametric prostate MRI" (bpMRI) including the T2WI and DWI sequences alone to overcome the drawbacks of DCE. The advantages of such limited protocol MRI are lower costs, shorter console times and negligible risk of adverse events with contrast agents.[48] It was estimated that the total cost is halved (600 vs 300 USD) and the "in-gantry" stay time (45 vs 15 minutes) was reduced to 1/3rd in bpMRI than mpMRI.[29]

In a review comparing the diagnostic test accuracy of mpMRI and bpMRI in 9840 biopsy naïve men, the pooled analyses demonstrated no significant difference in the diagnostic accuracy of detecting PCa between the two MRI protocols. Also, mpMRI and bpMRI did not differ in the sensitivity (86% vs 90%) and specificity (73% vs 70%) of PCa detection. Thus, bpMRI may serve as a quick, cheap, contrast-free alternative to mpMRI.[49]

Robot-assisted MRGB

Recently, a MR compatible robot, MrBot has been FDA approved for robotic-assisted MRGB based on a small-scale human trial. In five men, the needle is steered remotely from outside the gantry and transperineal MRGB were performed using MrBot. Combined TB and SB were obtained and csPCa was detected in 40%. Importantly, the device achieved a targeting accuracy of 2.55 mm with no trajectory corrections and unsuccessful targeting attempts.[50]

Challenges ahead and future perspectives on MRI/TRUS fusion biopsy platforms

One of the most important challenges with currently available MRI/TRUS fusion biopsy platforms is the possible prostate deformation and patient movement during the procedure that alter MRI/TRUS co-registration. This results in loss of real-time accurate targeting. While such mistargeting can be tackled with "focal lesion saturation" by obtaining more targeted biopsies per lesion, MRI/TRUS fusion platforms will continue to evolve with in-built technologies correcting such misregistration. Future platforms may include auto-segmentation and deformable co-registration with motion compensation. When applied with improved USG resolution, these technical advancements further improve the targeting accuracy. Future developments may also incorporate additional USG techniques beyond gray-scale such as contrast-enhanced USG, elastography, color or power doppler USG to get more refined MRI/TRUS image fusion.[51]

Conclusion

The MRI-diagnostic pathway with mpMRI directed targeted biopsies can be performed by a variety of techniques to achieve increased detection of clinically significant PCa and avoid unnecessary biopsies. There appears no clear advantage between the three common techniques of MRGB. However, the cost and the availability of resources should be kept in mind in choosing the correct approach.

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