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A11(25) 2029

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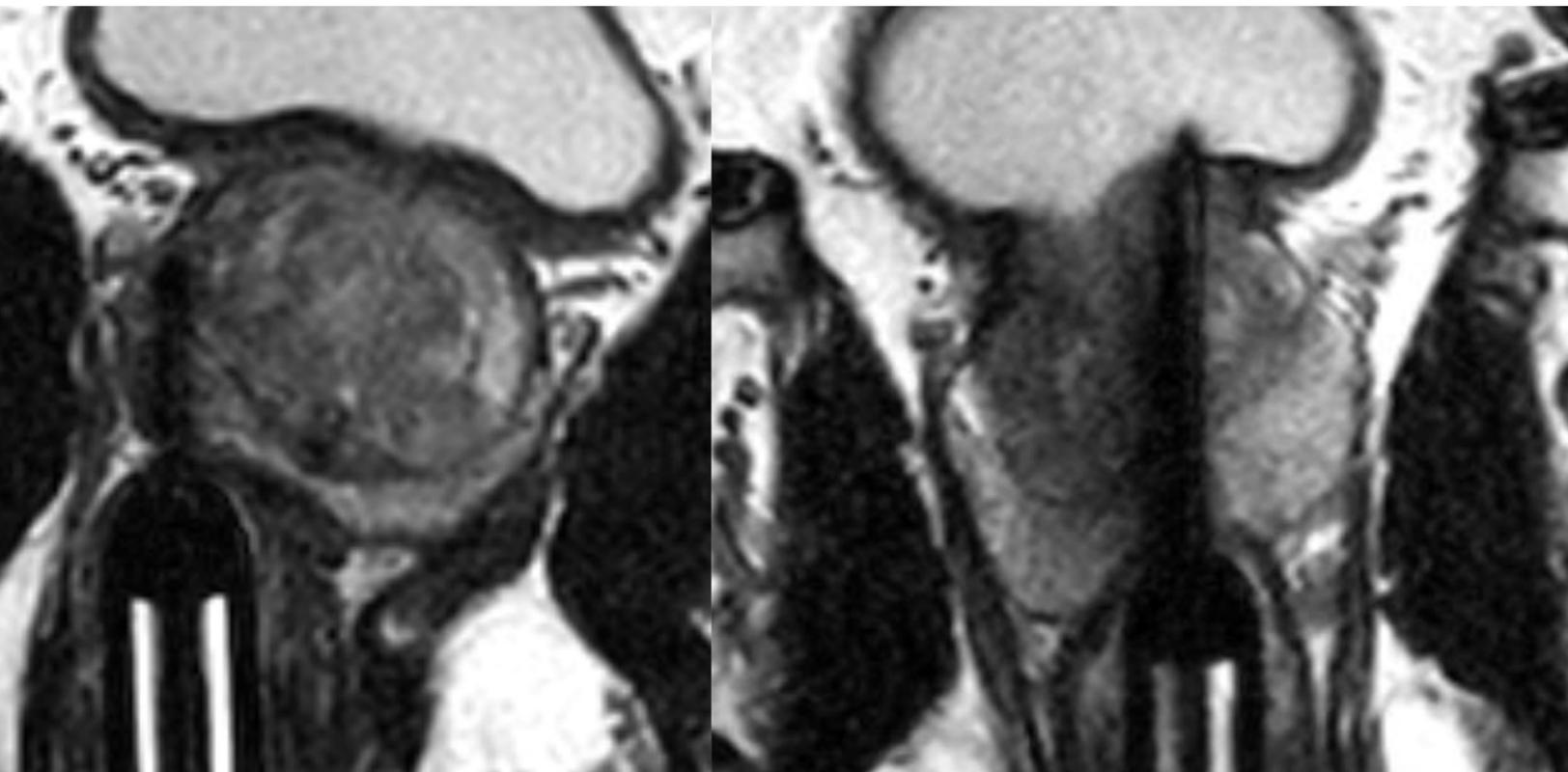
Direct MRI-guided In-Bore Targeted Biopsy of the Prostate: A Step-by-Step How To and Lessons Learned

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Multiparametric MRI—the most accurate imaging technique for detection of prostate cancer—has transformed the landscape of prostate cancer diagnosis by enabling targeted biopsies. In a targeted biopsy, tissue samples are obtained from suspicious regions identified at prebiopsy diagnostic MRI. The authors briefly compare the different strategies available for targeting an MRI-visible suspicious lesion, followed by a step-by-step description of the direct MRI-guided in-bore approach and an illustrated review of its application in challenging clinical scenarios. In this technique, direct visualization of the needle, needle guide, and needle trajectory during the procedure provides a precise and versatile strategy to accurately sample suspicious lesions, improving detection of clinically significant cancers.

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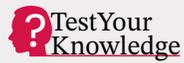


Introduction

Prostate biopsies are required for diagnosis and management in patients with suspected prostate cancer (1). With the broad spectrum of aggressiveness and the potential morbidity related to prostatectomy or radiation therapy, accurate pretreatment risk stratification of prostate cancer is crucial for preventing under- and overtreatment (2). Pretreatment

determination of prostate cancer aggressiveness is inferred from predictive models such as those derived from tables and nomograms combining demographic factors, serum prostate-specific antigen (PSA) values, results of digital rectal examination, and biopsy findings (International Society of Urological Pathology [ISUP] grade group, number of positive cores, and cancer core length in biopsy fragments) (3,4).

Supplemental Material



RadioGraphics 2024; 44(2):e230142
<https://doi.org/10.1148/rg.230142>

Content Codes: GU, IR

Abbreviations: ADC = apparent diffusion coefficient, DWI = diffusion-weighted imaging, ISUP = International Society of Urological Pathology, PI-RADS = Prostate Imaging Reporting and Data System, PSA = prostate-specific antigen, TRUS = transrectal US

TEACHING POINTS

- Multiparametric MRI has enabled targeted biopsies to improve detection and characterization of prostate cancers.
- Three techniques have been described for performing targeted biopsies of suspicious lesions identified at prostate MRI: (a) cognitive MRI-US fusion, (b) software-assisted MRI-US fusion, or (c) direct MRI-guided in-bore biopsy.
- However, in many instances the clinical scenario or the procedure itself presents challenges that can benefit from the detailed anatomic depiction and versatility offered by in-bore biopsy.
- Gross patient motion, subtle and involuntary motion, or changes in the anatomy secondary to introduction and repositioning of the biopsy devices are obstacles that may affect sampling accuracy.
- The direct visualization of the lesion, needle guide, and needle trajectory during MRI-guided in-bore biopsy provides a precise and versatile strategy for accurately sampling suspicious lesions in patients undergoing targeted biopsy.

Prostate biopsies were traditionally performed using a US-guided anatomy-based approach (1), radically different from biopsies for other diseases, such as breast or thyroid cancer, in which biopsies are directed to sites of imaging or physical examination abnormalities. In this so-called systematic approach, the biopsy operator uses a US transducer to locate and sample different regions of the prostate, frequently following a 12-core template of the lateral and medial aspects of the right and left base, mid, and apex of the gland. This systematic nontargeted technique frequently misses—sensitivity of only 48%—or underestimates clinically significant cancers and contributes to overdiagnosis by identifying indolent tumors (5). Consequently, these biopsy results can lead to suboptimal assessment of the disease volume, extent, and aggressiveness, resulting in increased uncertainty and potential undertreatment of men with aggressive cancers. For these reasons, alternative biopsy approaches have emerged in recent years.

Adoption of multiparametric MRI as a prostate biopsy triage and planning tool has transformed the landscape of prostate cancer diagnosis. By combining the anatomic information from T2-weighted imaging, the functional information from diffusion-weighted imaging (DWI) and dynamic contrast-enhanced imaging, and the common language from the Prostate Imaging Reporting and Data System (PI-RADS) (6), multiparametric MRI has enabled targeted biopsies to improve detection and characterization of prostate cancers (7,8). For example, in the Prostate Magnetic Resonance Imaging Study (PROMIS), use of an MRI-based triage approach allowed 27% of men to avoid biopsy while allowing detection of 18% more cases of clinically significant cancers and 5% fewer clinically insignificant cancers (5).

In this article, after briefly comparing the different techniques available for targeting an MRI-visible suspicious lesion, we provide a detailed description of the direct in-bore MRI-guided biopsy technique.

Targeted Biopsy Techniques

Three techniques have been described for performing targeted biopsy of suspicious lesions identified at prostate MRI: (a) cognitive MRI-US fusion, (b) software-assisted MRI-US fusion, or (c) direct MRI-guided in-bore biopsy (9). A transrectal or transperineal route can be chosen with any of these techniques; a discussion of the advantages and disadvantages of these two routes is beyond the scope of this article.

Some studies compared the diagnostic accuracy of the targeting techniques with conflicting data regarding which is the most precise. For example, the Functional Testing Underlying Coronary Revascularization (FUTURE) trial (10) did not reveal a significant difference in cancer detection rates between the three techniques available. Despite intuitive expectations that software-assisted fusion would be more accurate than cognitive fusion, particularly for lesions that are not well seen at US, there is a paucity of evidence to support this observation (11). Of nine studies that compared these two US-based fusion approaches (12–20), most did not show a significant difference, while some (12,14–17,19) showed a higher cancer detection rate with software-assisted fusion compared with cognitive fusion. This superiority appeared more relevant in men with small lesions (14,19) or lesions in the anterior gland (12,14,15).

Comparisons between the sampling accuracy of in-bore biopsy versus software-assisted fusion biopsy also show conflicting data. A randomized study (21) did not reveal a significant difference in cancer detection rates between these two techniques. Conversely, some studies have shown higher detection of clinically significant cancers (22–25), stronger concordance between pre- and postoperative cancer grade (26), and higher per-core percentage of cancer (27) with in-bore biopsy than with MRI–transrectal US (TRUS) fusion biopsy, suggesting potential improved sampling accuracy with the in-bore approach. For instance, in one of these studies, MRI-US fusion revealed clinically significant prostate cancer in 37% and 78% of the PI-RADS category 4 and 5 lesions, respectively, in comparison with 64% and 91% of the lesions sampled using an in-bore approach (24).

Cognitive MRI-US Fusion Biopsy

In this approach, the goal is to combine the diagnostic accuracy offered by multiparametric MRI with the availability and versatility of US. This is performed without direct overlay of the MR images onto the US images, and the targeting is based on the operator's awareness of the prostate anatomy and imaging. Occasionally, this may include directly visualizing the same lesion seen at MRI and US in the same location. However, most frequently, the operator of the US-guided biopsy reviews the location of a lesion identified at multiparametric MRI and translates that information to the anatomic site to be targeted during the US-guided biopsy in a cognitive fashion (eg, anterior left transition zone at the base of the prostate). Use of landmarks (eg, cystic benign prostatic hyperplasia [BPH] nodules)

can compensate for differences in planes between the two modalities (28).

This technique requires no additional hardware and is therefore less costly. If desired, systematic sampling of the prostate can also be performed at the time of the targeted biopsies of the MRI-visible lesions. However, this technique is heavily operator dependent and vulnerable to misregistration (29,30).

Software-assisted MRI-US Fusion Biopsy

This technique leverages software-based image registration that generates an overlay of the MRI-visible lesions onto the real-time depiction of the prostate on a US screen (Fig S1), potentially improving sampling accuracy compared with that of the cognitive approach (29). Several steps are required for a successful procedure (9), including (a) prostate contouring, (b) lesion identification and (c) lesion contouring at prebiopsy diagnostic multiparametric MRI, (d) prostate contouring at US, and (e) fusion of the data from both modalities by the MRI-US fusion system. Each of these steps contributes to the accuracy of image registration.

Therefore, inaccurate segmentation of the MR or US images due to operator error or to inherent limitations of either modality can lead to suboptimal coregistration and subsequent sampling error (31). Additionally, the MRI-TRUS fusion system operates under the assumption that tissues remain static, making it difficult to account for motion or tissue displacement that may occur during the procedure (ie, respiration, peristalsis, prostate or target lesion displacement by probe or biopsy needle insertion).

Direct MRI-guided In-Bore Biopsy

In this technique, the biopsy is performed using an MRI-compatible device while the patient is lying in the MRI unit. The main advantage is direct visualization of the suspicious lesion, the needle guide, and the biopsy needle before, during, and after sampling. This allows precise sampling accuracy, real-time identification of unexpected suboptimal sampling, and prompt operator response with adjustments to optimize subsequent additional samples (32). Despite some discrepant reports, studies have shown a higher rate of detection of clinically significant cancers (24) and stronger concordance between pre- and postoperative cancer grade (26) with in-bore biopsy than with MRI-TRUS fusion biopsy.

This potential optimized sampling makes in-bore biopsy an excellent second-tier strategy offered to patients in a scenario such as prior fusion biopsy with negative results and highly suspicious lesions (PI-RADS category 4 or 5). This technique can also provide improved accuracy in challenging clinical scenarios such as small lesions in a large gland or suspected local recurrence after surgery. A disadvantage of in-bore biopsy is the higher cost. Also, because systematic sampling is not routinely performed during in-bore biopsy, MRI-invisible lesions could be missed with this approach.

Elements and Steps of Direct MRI-guided In-Bore Biopsy

The multidisciplinary team, resources, and protocols used for direct MRI-guided prostate biopsy may vary between

different institutions. Here, we provide a description of the approach used at our institution.

Team

Schedulers, nurses, MRI technologists, advanced practice providers (APPs), and radiologists are part of the team caring for biopsy patients. Schedulers participate by providing patients with the preprocedure preparation, which is discussed later. Nurses receive the patient in the preparation and recovery area, administer prebiopsy antibiotics and a saline laxative enema (C.B. Fleet) if a transrectal approach will be used, support moderate sedation and postbiopsy recovery, and provide discharge instructions. MRI technologists ensure that the supplies needed for each biopsy are available and are familiar with MRI-specific safety considerations, patient positioning, and imaging protocols.

Under the supervision of a radiologist, an APP may serve as the initial provider to explain the procedure to the patient and obtain their consent. The radiologist reviews prebiopsy images to assess the location(s) of the target(s) and performs the targeted biopsy. Additionally, an APP can be further involved in assisting with the in-bore procedure, helping to position the patient and manipulate the device.

Procedure Duration and Scheduling

In a recent publication, our group reported a mean (\pm standard deviation) biopsy duration of 58 minutes \pm 23 (range, 25–140 minutes) (33). As expected, the duration of the procedure increased with the number of lesions: in men with one, two, three, four, and five lesions, respectively, the mean (\pm standard deviation) biopsy duration was 41 minutes \pm 9 (range, 25–70 minutes), 65 minutes \pm 12 (range, 40–140 minutes), 92 minutes \pm 20 (range, 60–138 minutes), 114 minutes \pm 15 (range, 95–140 minutes), and 134 minutes \pm 5 (range, 129–139 minutes) (33). At our institution, there is no maximum number of lesions to be biopsied. Because most patients have one to three lesions, each patient is scheduled for a 90-minute slot.

Patient Preparation

Patients are instructed to not take anticoagulant drugs—including aspirin—for 7 days before the biopsy, to not eat or drink after midnight, and to have a driver available to take them back to their chosen destination after completion of the biopsy, given administration of moderate sedation (discussed later). An enema is performed on patient arrival, and antibiotic prophylaxis is administered approximately 1 hour before the procedure if a transrectal approach will be used. Antibiotic options include targeted prophylaxis if a rectal swab (34) was performed or 1 g of intravenous ceftriaxone.

Devices

The in-bore biopsy can be performed using one of two commercially available MRI-compatible devices (DynaTRIM, In-vivo; Remote Controlled Manipulator [RCM], Soteria Medical). These systems consist of a portable platform placed on the MRI unit table, attached to a needle guide that can be manipulated in all directions either manually (DynaTRIM) or remotely by pneumatic air stepper motors (Fig 1). The DynaTRIM system is

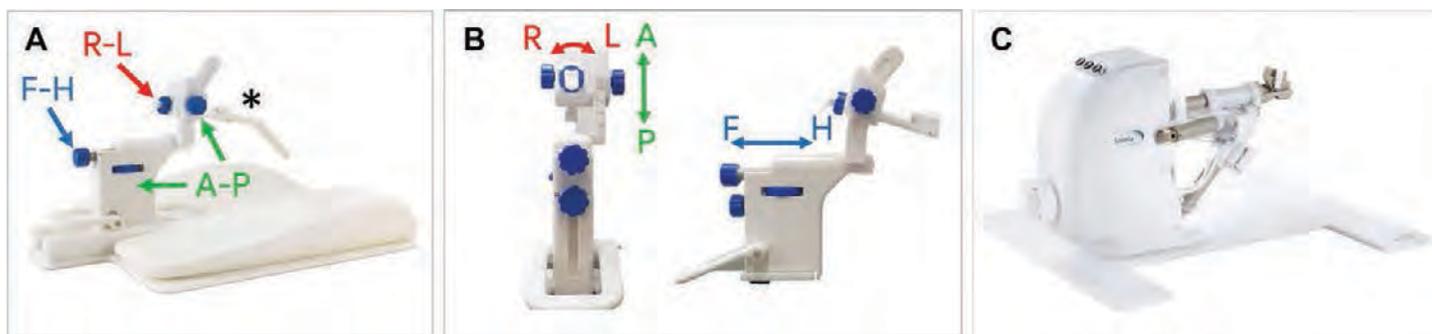


Figure 1. Commercially available in-bore biopsy systems. Both the DynaTRIM (A, B) and Soteria (C) systems consist of a portable platform placed on the MRI unit table, to which a needle guide (* in A) can be connected. (A, B) In the DynaTRIM device, the position of the needle guide can be manually changed in the foot (F) to head (H), right (R) to left (L), and anterior (A) to posterior (P) directions. (C) The Soteria system is remotely controlled through pneumatic air stepper motors.

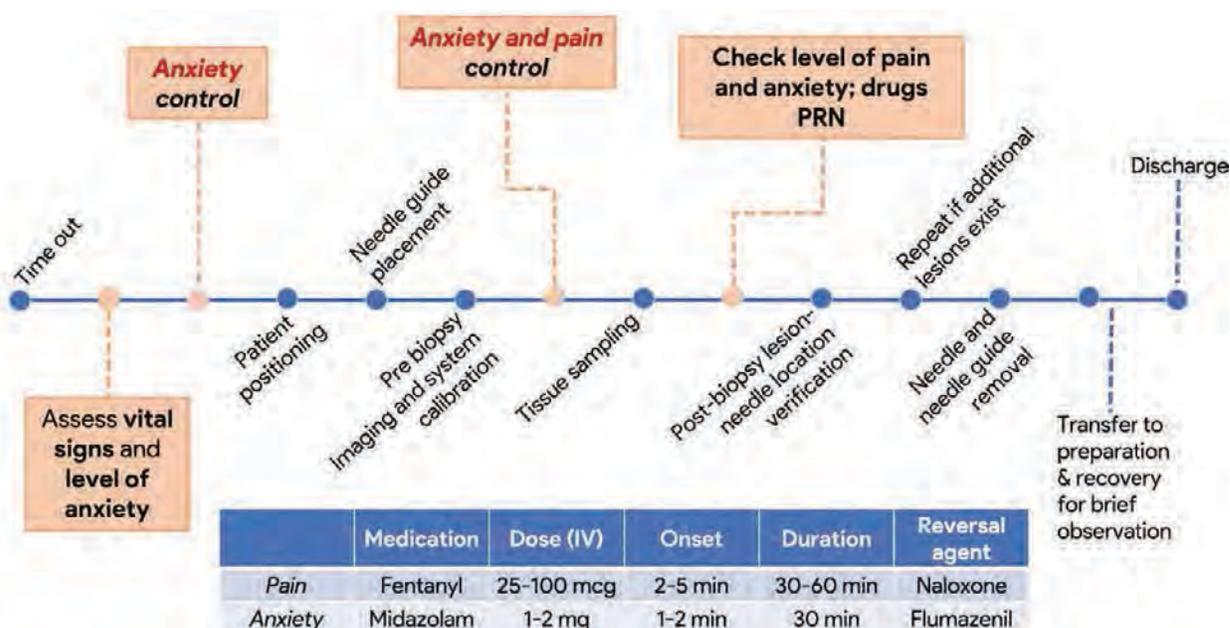


Figure 2. Time points of an in-bore biopsy, steps, and drugs used for moderate sedation. The focus of moderate sedation moves from anxiety control at the beginning of the procedure to pain control immediately before tissue sampling. This systematic approach increases patient comfort, which translates into reduced motion and efficient imaging and tissue sampling. IV= intravenous, PRN = pro re nata (as needed).

less costly and has been on the market for a longer time, while the RCM system has the potential to save time and the convenience of remote control of the needle guide position.

Patient Positioning and Moderate Sedation

Figure 2 demonstrates the workflow of an in-bore biopsy and the medications used to manage patient anxiety and pain. While moderate sedation is initiated, the patient is placed in the prone position and aligned with the biopsy system and MRI unit table. A phased-array surface coil is placed covering the lower abdomen and pelvis (Fig 3).

Needle Guide Insertion

After the patient is properly positioned, 10 mL of 2% lidocaine gel is administered rectally, and a disposable needle guide is

inserted into the rectum when a transrectal route is used. The needle guide is subsequently attached to the needle guide holder on the biopsy platform.

Imaging

Figure 4 provides an illustration of the different imaging components of an in-bore biopsy.

Verification of Baseline Position of the Needle Guide.—After needle guide insertion, sagittal T2-weighted images are acquired to assess the position of the needle guide relative to the prostate. The goal of the initial placement is to have the tip of the needle guide abut the posterior margin of the prostate, without deforming the prostate contour, near the apex. If correction is necessary, repeat imaging is performed (Fig 5).

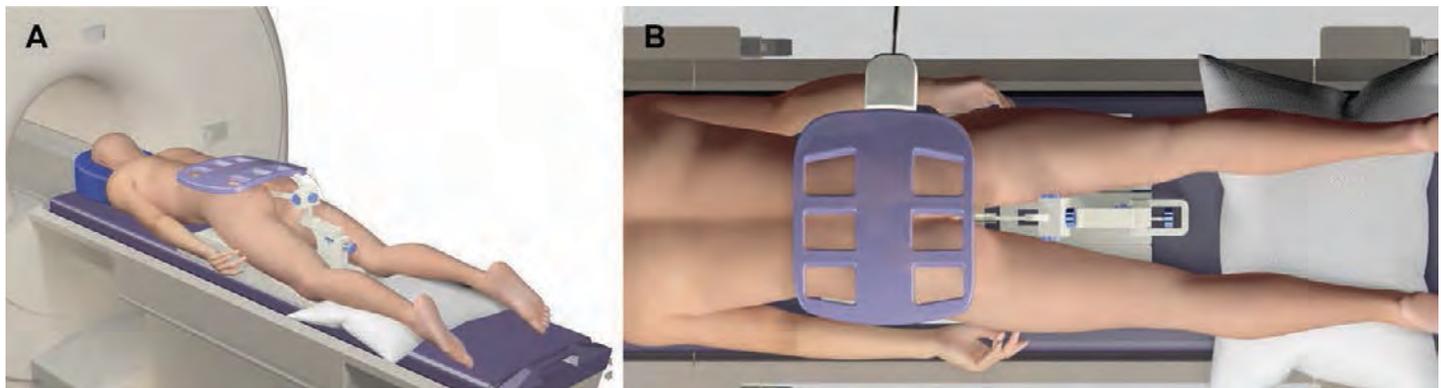


Figure 3. Patient positioning. **(A)** The biopsy is performed with the patient in the prone position. **(B)** It is important to ensure that the patient is properly centered relative to the width of the MRI unit's table and that the biopsy system is aligned with the gluteal cleft. This improves patient comfort and decreases the resistance offered by the perineal soft tissues when the needle guide needs to be repositioned. Also note the optimal position of the phased-array torso coil, providing adequate coverage of the lower pelvis.

Once properly positioned, these images are sent to the post-processing workstation for calibration.

Correlation of Presampling Imaging with Diagnostic MRI (Target Identification).—After the needle guide is properly positioned, axial T2-weighted images are obtained through the prostate and correlated with the prior diagnostic MR images to identify the lesion(s) of interest. These images—which can be acquired using a high-resolution turbo spin-echo or single-shot fast spin-echo sequence, depending on lesion conspicuity on the prebiopsy diagnostic images—are sent to the postprocessing software and used to define the target(s).

This is a critical step that requires expertise in interpretation of prostate MR images to ensure accurate targeting, as the images acquired during the procedure may not be of comparable quality to the prebiopsy MR images. If a lesion is poorly visible at T2-weighted imaging and more conspicuous at DWI (Fig 6) or if there is marked tumor heterogeneity and sampling of specific areas within the lesion is desired (Fig 7), DWI may be performed after the corresponding T2-weighted imaging to facilitate accurate sampling of the most concerning areas (35,36).

Needle Guide Repositioning and Verification of Guide-Lesion Alignment.—With information from steps A (needle guide positioning) and B (target location), the postprocessing software determines the optimal needle length and the changes needed to the guide position to properly align with the lesion. Changes can be made in multiple different directions. After these changes are made, T2-weighted images are obtained along the long axis of the needle guide to determine proper guide-lesion alignment. DWI may also be performed in the oblique plane to assist with lesion identification. Since the coordinates provided by the system assume that all structures remain static during manipulation of the needle guide, fine-tuning adjustments may be needed (Fig S2).

Tissue Sampling and Verification of Needle-Lesion Location.—On verification of the correct alignment of the needle

guide and that the appropriate needle length has been chosen, an 18-gauge MRI-compatible core biopsy gun is inserted through the needle guide and fired. With the needle in place, imaging is repeated to document that the needle followed the expected trajectory, without significant anatomic changes (ie, needle penetration through the prostate pseudocapsule can cause prostate deformation and displacement of the lesion of interest), therefore with optimal lesion sampling (Fig 8).

Usually, three cores (33) are obtained from each target, and the location and number of subsequent cores are determined after assessing the adequacy of the initial sampling. The additional cores can be obtained after stepwise needle guide repositioning aiming to sample different areas of the lesion, in some cases without the need for repeat imaging to verify every single additional core.

Specimen Handling

After each needle pass, the biopsy gun is opened to expose the core biopsy specimen and gently rubbed against a pad to remove the tissue, which is then transferred to a small bottle prefilled with 10 mL of 10% neutral buffered formalin (Fig S3). At our institution, each core from each lesion is stored and labeled separately (eg, lesion 1 in the right apical posterolateral peripheral zone, core 1).

Patient Recovery

After tissue sampling, the needle guide is removed and the patient is transferred to the preparation and recovery area. The patient is informed that his urine and semen may be tinged with blood and that a few blood clots may be passed in the urine, stool, or semen for 1–2 weeks. Patients receive verbal and written information about the signs and symptoms of urinary retention (reported retention rates for transrectal and transperineal US-based approaches are 0.8%–1.7% and 6.7%, respectively [37]) and infection (reported infection rates for TRUS biopsy range from 0.7% to 7.0% [38]), upon which they should promptly visit the nearest emergency room. Patients are then discharged and encouraged to drink plenty of fluids. When applicable, use of anticoagulants may resume a few days after an uneventful biopsy.

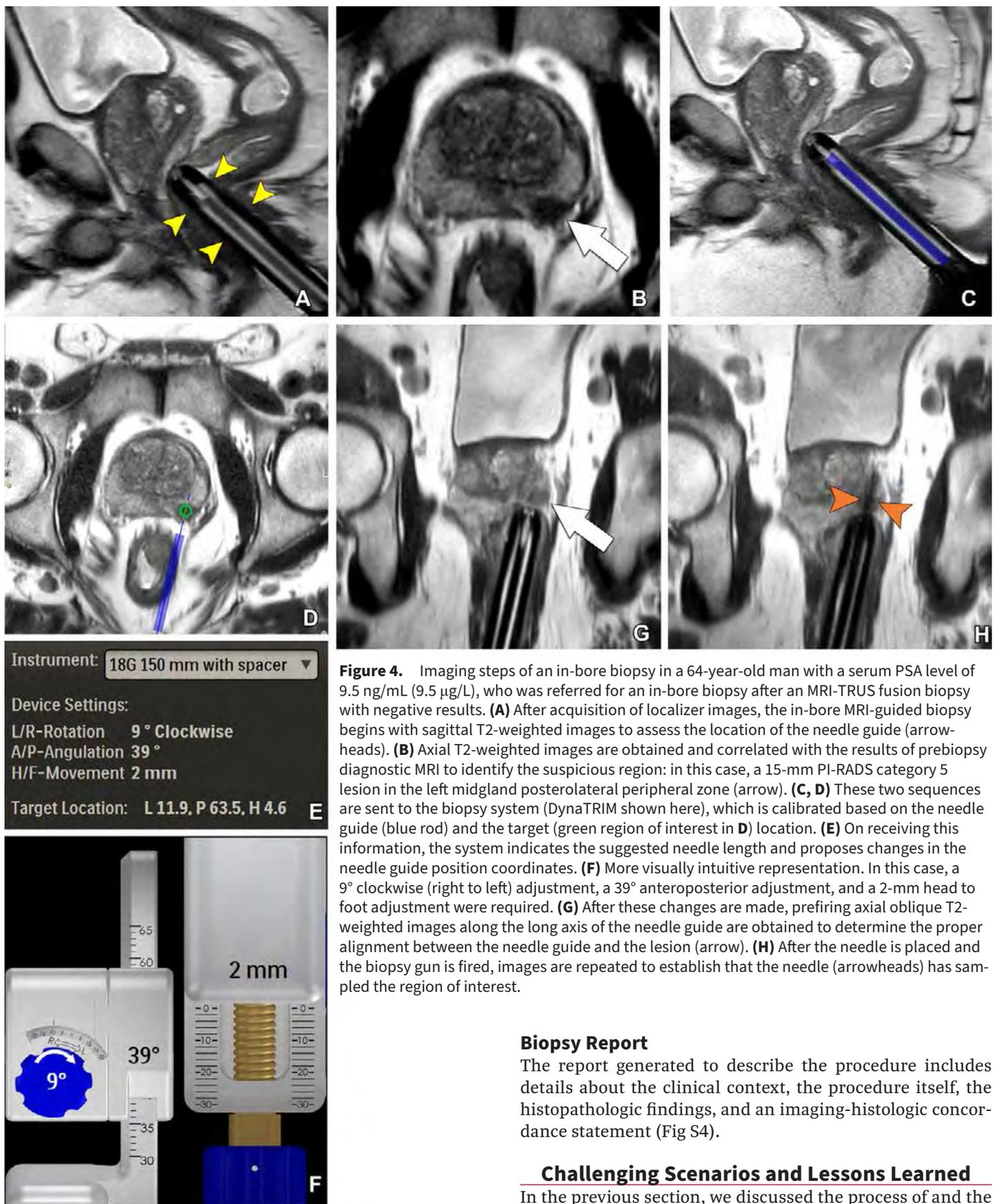


Figure 4. Imaging steps of an in-bore biopsy in a 64-year-old man with a serum PSA level of 9.5 ng/mL (9.5 µg/L), who was referred for an in-bore biopsy after an MRI-TRUS fusion biopsy with negative results. **(A)** After acquisition of localizer images, the in-bore MRI-guided biopsy begins with sagittal T2-weighted images to assess the location of the needle guide (arrowheads). **(B)** Axial T2-weighted images are obtained and correlated with the results of prebiopsy diagnostic MRI to identify the suspicious region: in this case, a 15-mm PI-RADS category 5 lesion in the left midgland posterolateral peripheral zone (arrow). **(C, D)** These two sequences are sent to the biopsy system (DynaTRIM shown here), which is calibrated based on the needle guide (blue rod) and the target (green region of interest in **D**) location. **(E)** On receiving this information, the system indicates the suggested needle length and proposes changes in the needle guide position coordinates. **(F)** More visually intuitive representation. In this case, a 9° clockwise (right to left) adjustment, a 39° anteroposterior adjustment, and a 2-mm head to foot adjustment were required. **(G)** After these changes are made, preferring axial oblique T2-weighted images along the long axis of the needle guide are obtained to determine the proper alignment between the needle guide and the lesion (arrow). **(H)** After the needle is placed and the biopsy gun is fired, images are repeated to establish that the needle (arrowheads) has sampled the region of interest.

Biopsy Report

The report generated to describe the procedure includes details about the clinical context, the procedure itself, the histopathologic findings, and an imaging-histologic concordance statement (Fig S4).

Challenging Scenarios and Lessons Learned

In the previous section, we discussed the process of and the steps involved in a usual in-bore biopsy that follows the expected sequence of events. However, in many instances the clinical scenario or the procedure itself presents challenges

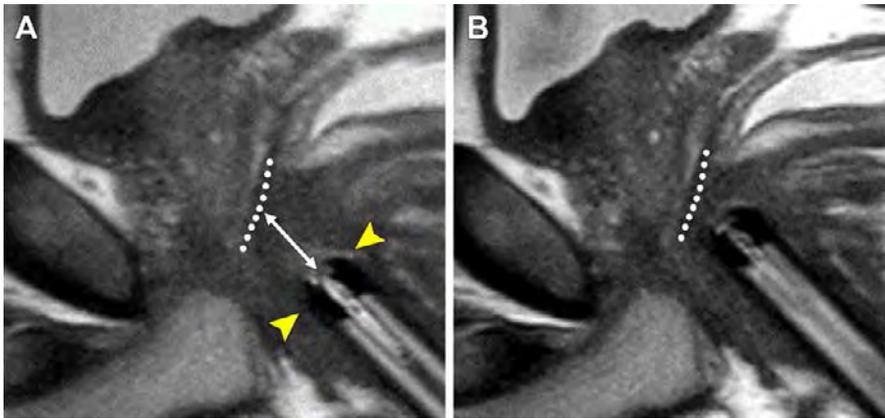


Figure 5. Verification of baseline position of the needle guide. **(A)** Initial sagittal T2-weighted image shows a wide gap (double-headed arrow) between the tip of the needle guide (arrowheads) and the posterior aspect of the prostate (dotted line). The needle guide was advanced. **(B)** Repeat imaging confirms proper position of the needle guide. Dotted line = posterior aspect of the prostate.

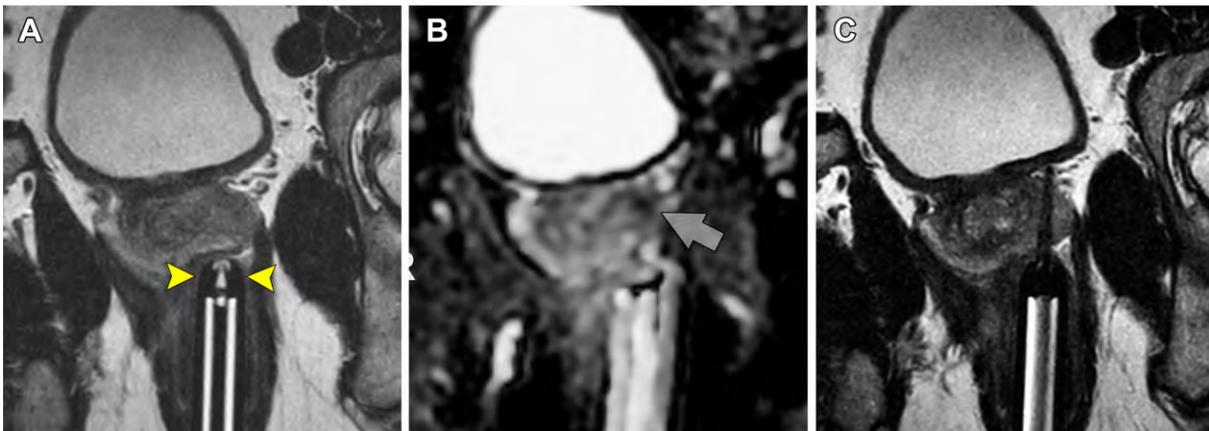


Figure 6. Use of DWI for increased lesion conspicuity during in-bore biopsy. **(A)** Prefiring oblique T2-weighted image along the long axis of the needle guide (arrowheads) shows a diffusely hypointense region in the left hemigland peripheral zone, without a discernible focal lesion. **(B, C)** Corresponding apparent diffusion coefficient (ADC) map **(B)** derived from DWI better depicts the suspicious lesion (arrow in **B**), improving sampling accuracy **(C)**. Biopsy revealed ISUP grade group 4 adenocarcinoma.

that can benefit from the detailed anatomic depiction and versatility offered by in-bore biopsy. In this section, we discuss some common examples.

Learning Curve

In-bore MRI-guided biopsy requires expertise in interpretation of prostate MRI to ensure accurate targeting, as the images acquired during the procedure may not be of comparable quality and do not conform to standard imaging planes familiar to the nonexpert radiologist. Therefore, in general, in-bore MRI-guided biopsy is typically performed by radiologists experienced in prostate imaging.

Motion

Gross patient motion, subtle and involuntary motion, or changes in the anatomy secondary to introduction and repositioning of the biopsy devices are obstacles that may affect sampling accuracy. These can be the result of restlessness secondary to anxiety or pain, discomfort related to the prone position and sometimes difficult arm positioning, or a hypermobile prostate caused by needle deflection due to pelvic floor laxity or shifting of the gland during the needle insertion. Also, when the guide is inserted too far, it deforms the prostate and displaces the target out of its expected position.

Gross motion of the gland can result in blurred images, particularly affecting identification of small lesions. The direct visualization of the biopsy device and structures of interest before and after sampling allows recognition and correction of these situations (Fig 9).

Suspicious Lesions That Are Very Small or in Challenging Locations

In-bore biopsy can be performed for lesions of any size and location within the prostate. However, small lesions—especially in larger prostates or tricky locations—can be more challenging to biopsy and prone to sampling errors. Small lesions far at the anterior base in a large prostate can be particularly difficult, and far apical lesions in an obese patient can also be harder to reach and require further adjustments.

However, although these situations present as a challenging scenario, it can be argued that the in-bore method can be superior to fusion biopsies in these cases, since poor sampling can be identified and adjusted for during the procedure. Small lesions anterior to the urethra may result in a needle trajectory that includes the urethra, which may result in a greater degree of hematuria and patient discomfort. An example of a very small lesion in a challenging location is a plaque-like, thin, and peripheral subcapsular lesion (Fig S5).

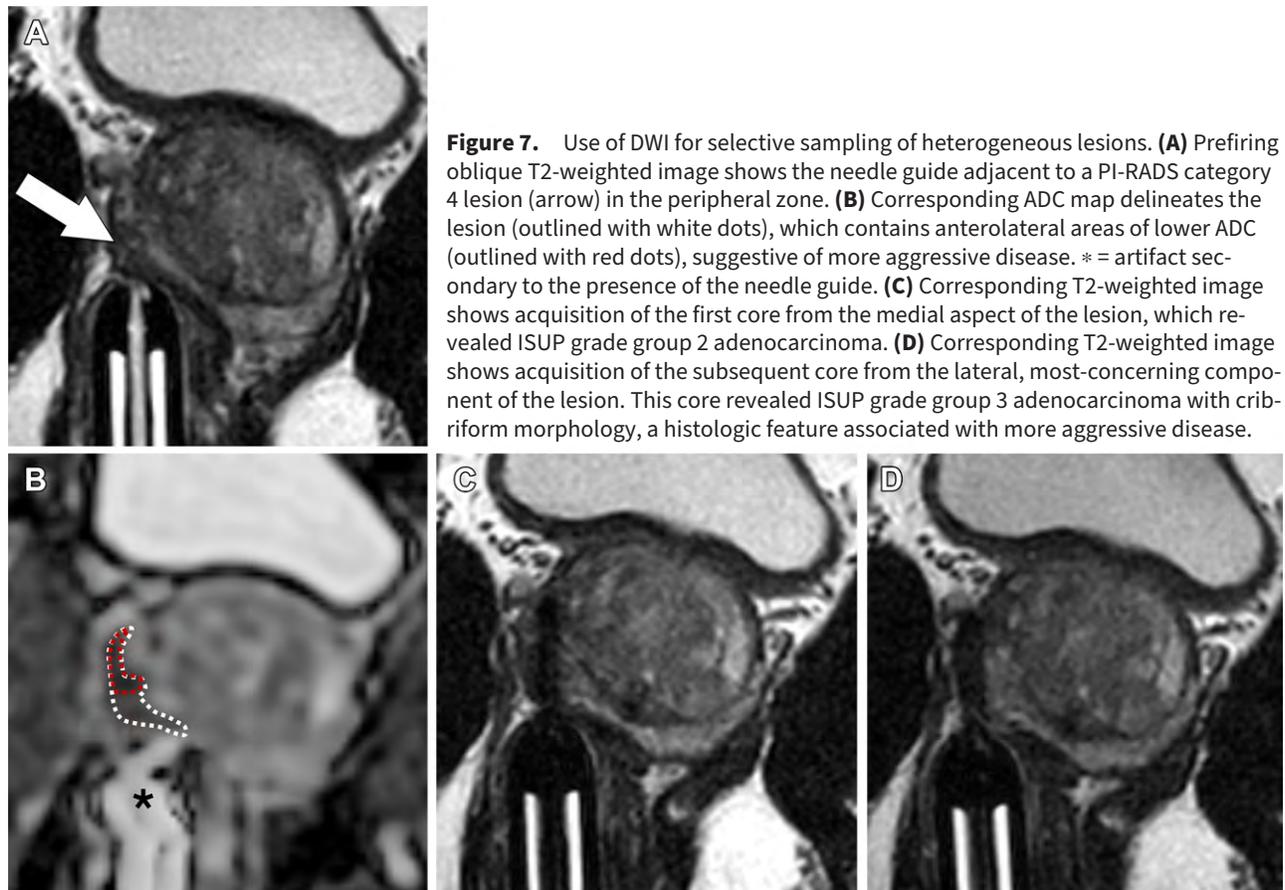


Figure 7. Use of DWI for selective sampling of heterogeneous lesions. **(A)** Prefiring oblique T2-weighted image shows the needle guide adjacent to a PI-RADS category 4 lesion (arrow) in the peripheral zone. **(B)** Corresponding ADC map delineates the lesion (outlined with white dots), which contains anterolateral areas of lower ADC (outlined with red dots), suggestive of more aggressive disease. * = artifact secondary to the presence of the needle guide. **(C)** Corresponding T2-weighted image shows acquisition of the first core from the medial aspect of the lesion, which revealed ISUP grade group 2 adenocarcinoma. **(D)** Corresponding T2-weighted image shows acquisition of the subsequent core from the lateral, most-concerning component of the lesion. This core revealed ISUP grade group 3 adenocarcinoma with cribriform morphology, a histologic feature associated with more aggressive disease.

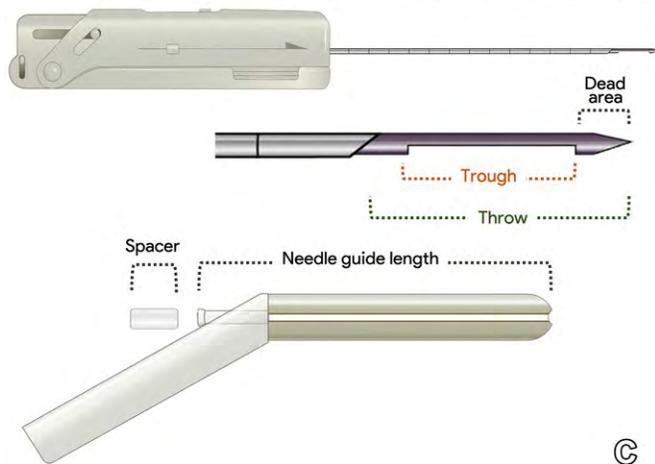


Figure 8. Choosing the right needle length for precise sampling of a small lesion in a 65-year-old man with negative results at MRI-TRUS fusion biopsy of a 5-mm PI-RADS category 4 lesion and persistently elevated serum PSA level, who was referred for a confirmatory in-bore biopsy. **(A)** Prefiring axial oblique T2-weighted image shows good alignment of the needle guide (arrowheads) and the target (arrow). **(B–D)** To ensure proper lesion sampling, especially in procedures impacted by motion or other unexpected changes in anatomy, the biopsy operator can verify the distance between the tip of the needle guide and the farther edge of the target (yellow dotted line in **B**), cross-referencing that information with the needle length recommended by the biopsy system (**C**), simulating the postfiring expected needle location, which is confirmed with postfiring imaging (**D**). Note the needle core design, with the trough where the tissue is collected, and the potential use of a spacer, which acts by shortening the net needle length by approximately 1.0 cm. This facilitates optimal sampling of this small lesion (arrow in **D**). Biopsy revealed ISUP grade group 3 adenocarcinoma.



Figure 9. Recognizing and compensating for anatomic changes during in-bore biopsy to improve sampling accuracy in a 66-year-old man with negative results at saturation biopsy and rising serum PSA level who underwent diagnostic MRI, which revealed a 10-mm PI-RADS category 4 lesion in the left base transition zone. **(A)** Prefiring axial oblique T2-weighted image shows good alignment between the needle guide and the lesion (arrow). **(B)** Initial postfiring image shows that needle insertion resulted in anatomic changes and that the sampled area (arrowheads) does not correspond to the region of interest. This core yielded no malignancy. The needle guide was repositioned to account for the unexpected deviation. **(C)** Corresponding image from second postfiring verification shows optimal position of the needle trough (arrowheads) relative to the lesion (arrow). This core revealed ISUP grade group 2 adenocarcinoma. Timely recognition and correction of tissue displacement during the procedure is one of the advantages of MRI-guided in-bore prostate biopsy.

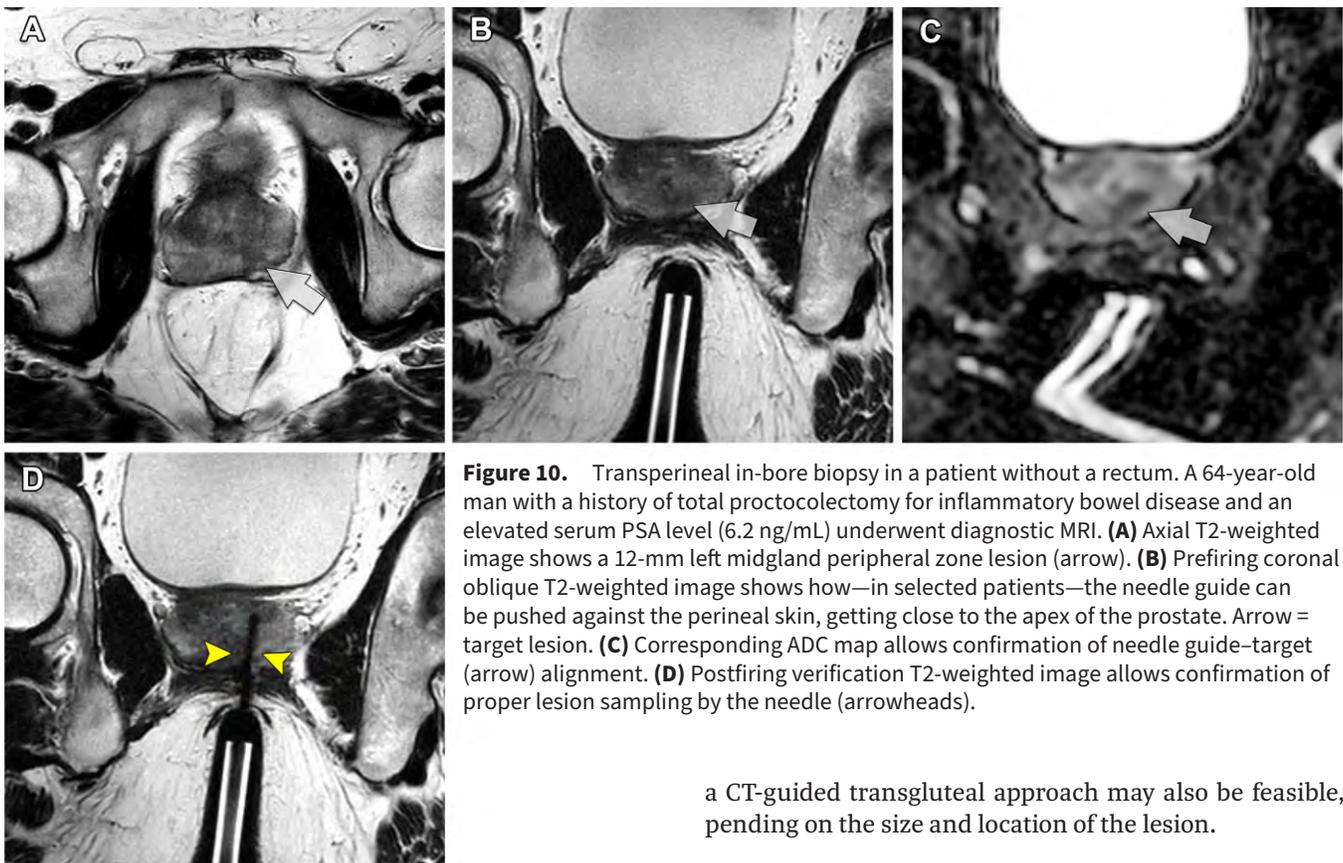


Figure 10. Transperineal in-bore biopsy in a patient without a rectum. A 64-year-old man with a history of total proctocolectomy for inflammatory bowel disease and an elevated serum PSA level (6.2 ng/mL) underwent diagnostic MRI. **(A)** Axial T2-weighted image shows a 12-mm left midgland peripheral zone lesion (arrow). **(B)** Prefiring coronal oblique T2-weighted image shows how—in selected patients—the needle guide can be pushed against the perineal skin, getting close to the apex of the prostate. Arrow = target lesion. **(C)** Corresponding ADC map allows confirmation of needle guide–target (arrow) alignment. **(D)** Postfiring verification T2-weighted image allows confirmation of proper lesion sampling by the needle (arrowheads).

Patient without a Rectum

In men without rectal access (eg, due to prior surgery), US-guided biopsy is limited due to the poor acoustic window offered by the transperineal US guidance. The sampling accuracy of the in-bore MRI-guided approach is not negatively affected in these patients, and both transperineal (Fig 10) and transgluteal (Fig S6) routes can be used (39). Alternatively,

a CT-guided transgluteal approach may also be feasible, depending on the size and location of the lesion.

Suspected Local or Regional Recurrence of Prostate Cancer

Patients with suspected disease recurrence after prostatectomy may not be good candidates for US-guided biopsy due to the poor delineation with US of soft-tissue nodules within postsurgical changes in the prostatectomy fossa. Moreover, software-assisted fusion biopsy requires contouring of the prostatic boundaries, a step that cannot be done after the gland has been resected. Direct in-bore MRI-guided biopsy

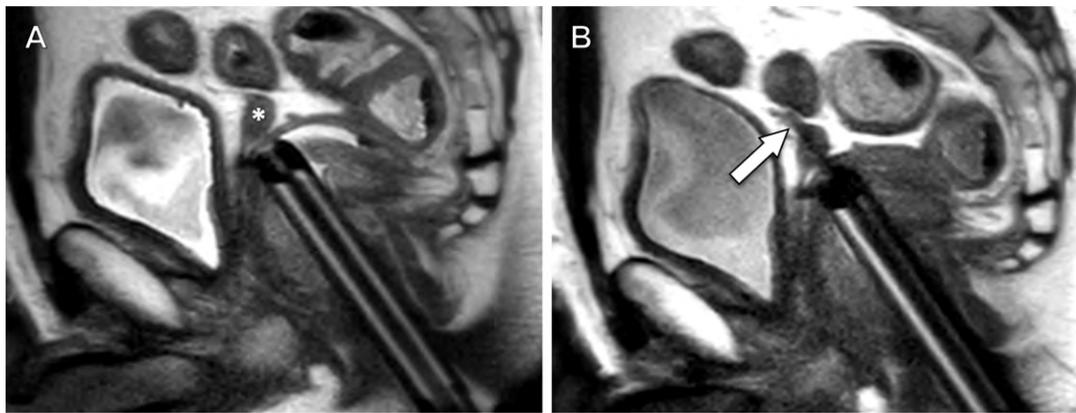


Figure 11. Postprostatectomy suspected local cancer recurrence in a 67-year-old man with rising serum PSA level after prostatectomy. **(A)** Prefiring sagittal T2-weighted image shows the needle guide properly aligned with the suspicious soft-tissue nodule (*) near a seminal vesicle remnant. **(B)** This was followed by adequate sampling. Arrow = suspicious soft-tissue nodule. Biopsy demonstrated recurrent ISUP grade group 3 adenocarcinoma.

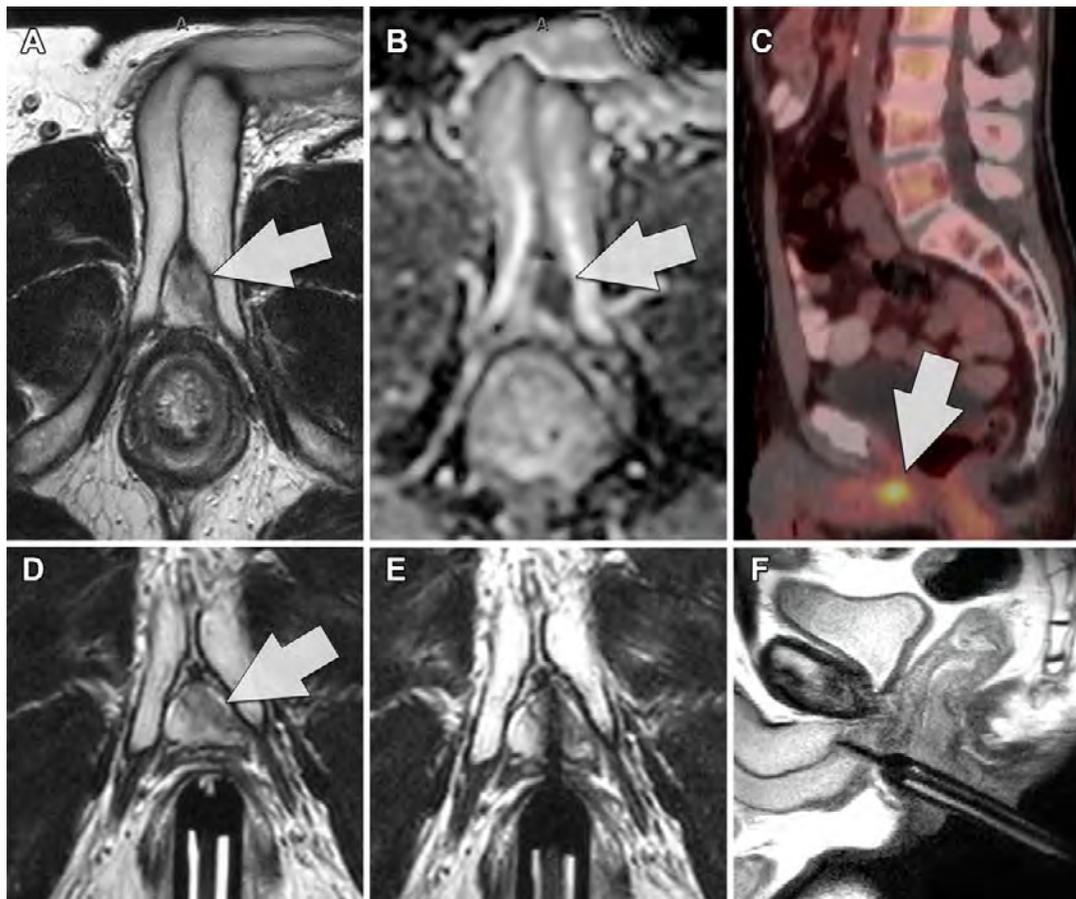


Figure 12. In-bore biopsy of suspected locoregional metastatic disease in a 66-year-old man with biochemical recurrence (rising PSA level; latest measurement, 3.6 ng/mL) 8 years after prostatectomy. Results of bone scanning were negative; he underwent prostate MRI, which revealed a suspicious 10-mm lesion at the base of the penis. **(A–C)** The lesion (arrow) is hypointense on an axial T2-weighted image **(A)** with marked restricted diffusion and low ADC **(B)**, concordant with a prostate-specific membrane antigen (PSMA)-avid area at subsequent PET/CT **(C)**. No other evidence of locally recurrent or metastatic disease was identified. **(D–F)** Oblique T2-weighted image **(D)** shows good prefiring needle guide-lesion (arrow) alignment, with good lesion sampling on postfiring oblique **(E)** and sagittal **(F)** T2-weighted images.

of local recurrent disease (Fig 11) and occasionally regional metastatic disease (Fig 12) can be considered in selected cases.

Prostate with Unusual Morphology

Changes in the prostate architecture secondary to previous procedures (eg, focal therapy [Fig 13]) may preclude accurate gland segmentation at MRI and US and thus compromise the precision of MRI-US image registration required for fusion biopsy. With the superior anatomic depiction offered by MRI and the lack of dependence on an intact prostate morphology, an in-bore biopsy approach may be beneficial in these patients.

Conclusion

The direct visualization of the lesion, needle guide, and needle trajectory during MRI-guided in-bore biopsy provides a precise and versatile strategy for accurately sampling suspicious lesions in patients undergoing targeted biopsy. Different imaging modalities, image registration techniques, and anatomic routes can be used to target a suspicious region identified within the prostate. It is important for radiologists to be familiar with the principles, advantages, and disadvantages of these various approaches. While it may be premature to state definitively which strategy is better, the improved sampling accuracy of MRI-guided in-bore biopsy should be recognized. More research is needed to explore

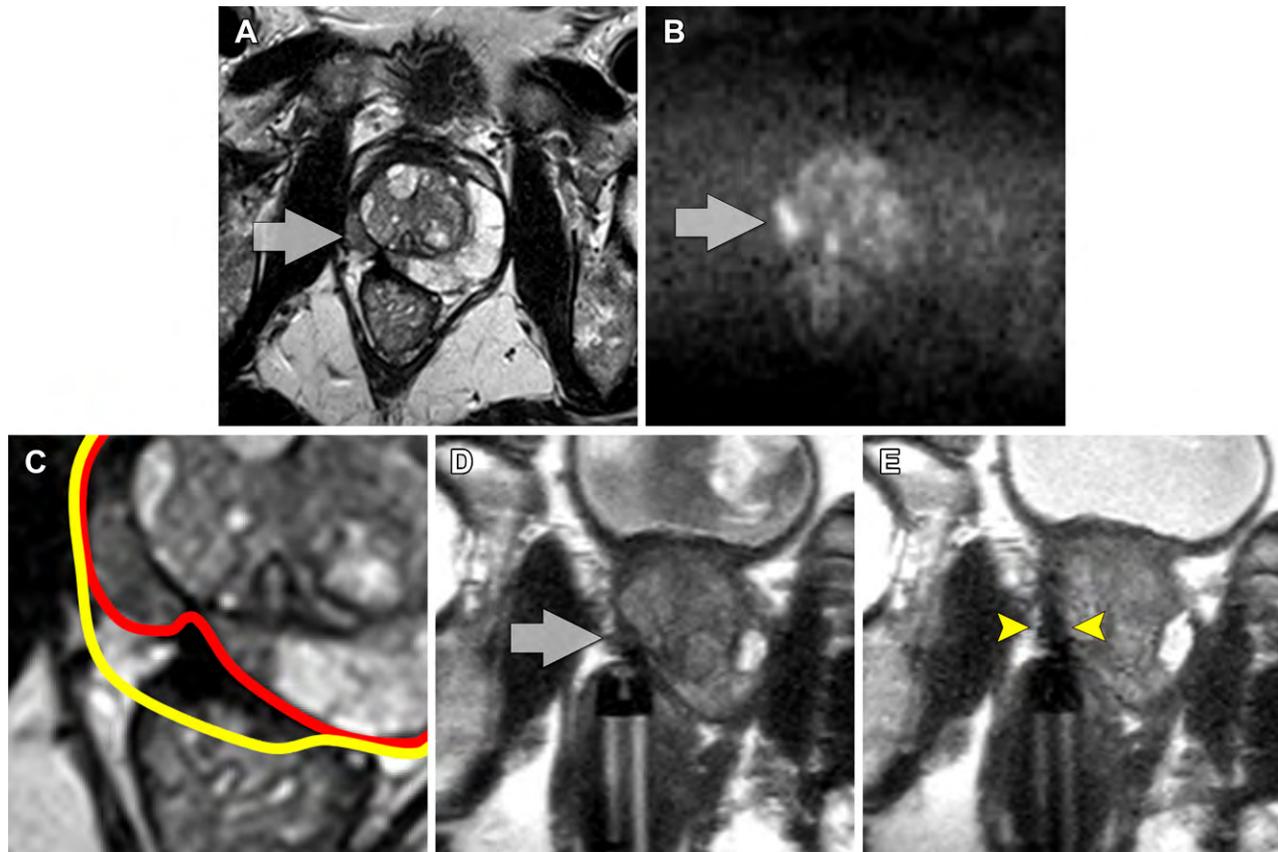


Figure 13. Changes in gland morphology after focal therapy in a 70-year-old man with rising serum PSA level after focal laser ablation for ISUP grade group 3 prostate cancer. Post-focal laser ablation diagnostic MRI was performed. (A, B) Axial T2-weighted (A) and diffusion-weighted ($b = 1500 \text{ sec/mm}^2$) (B) images show a PI-RADS category 4 lesion (arrow) in the right mid-gland lateral and posterior peripheral zone. (C) Note the parenchymal defect with retraction of the pseudocapsule in that region (actual prostate contours outlined in red, presumed preablation contours outlined in yellow). The patient underwent in-bore biopsy. (D, E) Prefiring oblique T2-weighted images show good needle guide-lesion (arrow) alignment (D) and adequate post-firing location of the needle (arrowheads in E). The superior delineation of the accurate prostatic contours with MRI compared with US suggests that in-bore biopsy would be less vulnerable to potential image registration misalignment than MRI-TRUS fusion biopsy. The biopsy demonstrated residual cancer, and the patient underwent repeat focal therapy.

factors that providers and patients must take into consideration, including availability, the learning curve, reproducibility, and cost.

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Acknowledgments.—We thank Erin Moore for her assistance with the illustrations.

Disclosures of conflicts of interest.—X.M. Grants from Simmons Cancer Center and Dedman Family Scholar program. All other authors have disclosed no relevant relationships.

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QUESTIONNAIRE

A11(25) Part 1 of 2

Direct MRI-guided In-Bore Targeted Biopsy of the Prostate: A Step-by-Step How to and Lessons Learned

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Question 1: What is the most accurate imaging technique for the detection of prostate cancer?

- A: Ultrasound
- B: CT
- C: Multiparametric MRI
- D: PET Scan

Introduction

Question 2: Which biopsy technique allows direct visualization of the lesion, needle guide, and needle trajectory during the procedure?

- A: Cognitive MRI-US Fusion
- B: Software-assisted MRI-US Fusion
- C: Direct MRI-guided in-bore biopsy
- D: Random systematic biopsy

Question 3: What is the sensitivity of the traditional systematic nontargeted biopsy technique for detecting clinically significant cancers?

- A: 48%
- B: 58%
- C: 68%
- D: 75%

Question 4: Fill in the missing percentages in the following statement.

“In the Prostate Magnetic Resonance Imaging Study (PROMIS), use of an MRI-based triage approach allowed% of men to avoid biopsy while allowing detection of% more cases of clinically significant cancers and% fewer clinically insignificant cancers”.

- A. 10% / 10% / 1%
- B. 15% / 18% / 2%
- C. 27% / 18% / 5%

Targeted Biopsy Techniques

Question 5: Which of the following statements are TRUE with reference to the three techniques described for performing targeted biopsy of suspicious lesions identified at prostate MRI?

- A: The Functional Testing Underlying Coronary Revascularization trial did not reveal a significant difference in cancer detection rates between the three techniques available
- B: Intuitive expectations that software-assisted fusion would be more accurate than cognitive fusion, particularly for lesions that are not well seen at US, have been proven correct
- C: The higher cancer detection rate shown in some studies of software- assisted fusion compared with cognitive fusion appeared more relevant in men with small lesions or lesions in the anterior gland

Question 6: Is the following statement **TRUE** or **FALSE**?

“Conversely, some studies have shown higher detection of clinically significant cancers, stronger concordance between pre- and postoperative cancer grade, and higher per-core percentage of cancer with in-bore biopsy than with MRI–transrectal US (TRUS) fusion biopsy, suggesting potential improved sampling accuracy with the in-bore approach”.

- A: TRUE
- B: FALSE

Question 7: What is a key advantage of in-bore biopsy over MRI-TRUS fusion biopsy in detecting clinically significant cancers?

- A: Lower cost
- B: Higher detection rate
- C: Shorter procedure time
- D: Easier to perform

Cognitive MRI-US fusion biopsy

Question 8: Which method of MRI-US fusion biopsy does **NOT** require additional hardware?

- A: Software-assisted MRI-US fusion
- B: Cognitive MRI-US fusion
- C: Direct MRI-guided in-bore biopsy
- D: Transrectal ultrasound-guided biopsy

Software-assisted MRI-US fusion biopsy

Question 9: In software-assisted MRI-US fusion biopsy?

- A. Sampling accuracy is potentially improved compared with that of the cognitive approach
- B. Two crucial steps are required for a successful procedure
- C. The system operates under the assumption that tissues remain static, making it difficult to account motion or tissue displacement

Direct MRI-guided in-bore biopsy

Question 10: In which scenario is in-bore MRI-guided biopsy particularly beneficial?

- A: Large prostate
- B: Prior negative fusion biopsy with negative results and highly suspicious lesions
- C: Initial diagnosis of prostate cancer
- D: Routine prostate screening

Question 11: Which two of the following are disadvantages of direct MRI-guided in-bore biopsy?

- A: Lower accuracy
- B: Higher cost
- C: MRI invisible lesions could be missed
- D: Difficulty in lesion identification

Elements and Steps of Direct MRI-guided In-Bore Biopsy

Procedure duration and scheduling

Question 12: What is the reported mean biopsy duration for a patient with one lesion?

- A: 25 minutes
- B: 41 minutes
- C: 65 minutes
- D: 90 minutes

Patient preparation

Question 13: Which of the following statements are TRUE with regard to patient preparation?

- A. Patients are instructed NOT to take anticoagulant drugs – including aspirin – for 7 days before the biopsy
- B. An enema is performed on patient arrival
- C. The patient is instructed to start with antibiotic prophylaxis 4 days before the biopsy

Patient positioning and sedation

Question 14: What is the duration of action of 25-100 mcg of fentanyl given IV?

- A: 15 – 20 minutes
- B: 30 - 60 minutes
- C: 45 – 90 minutes

Imaging

Question 15: Which MRI sequence is commonly used to assess the position of the needle guide relative to the prostate?

- A: Axial T1-weighted imaging
- B: Sagittal T2-weighted imaging
- C: Diffusion-weighted imaging
- D: Dynamic contrast-enhanced imaging

THE END

QUESTIONNAIRE
A11(25) Part 2 of 2
Direct MRI-guided In-Bore Targeted Biopsy
of the Prostate: A Step-by-Step How to and Lessons Learned

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Imaging continued

Question 1: Does the following statement describe a critical step that requires expertise in interpretation of prostate MR images to ensure accurate targeting?

“After the needle guide is properly positioned, axial T2-weighted images are obtained through the prostate and correlated with the prior diagnostic MR images to identify the lesion(s) of interest”.

- A:** YES
- B:** NO

Question 2: DWI can be performed

- A:** If a lesion is poorly visible at T2-weighted imaging and more conspicuous at DWI
- B:** If there is marked tumour heterogeneity
- C:** If sampling of specific areas within the lesion is desired
- D:** If a shorter procedure time is desired

Question 3: What is the typical number of biopsy cores obtained from each target during an in-bore biopsy?

- A:** One core
- B:** Two cores
- C:** Three cores
- D:** Four cores

Challenging Scenarios and Lessons Learned

Motion

Question 4: TRUE or FALSE?

"Gross patient motion, subtle and involuntary motion, or changes in the anatomy secondary to introduction and repositioning of the biopsy devices are obstacles that may affect sampling size."

- A:** TRUE
- B:** FALSE

Suspicious Lesions That Are Very Small or in Challenging Locations

Question 5: What type of lesions are more difficult to biopsy and prone to sampling errors?

- A:** Small lesions far at the anterior base in a large prostate
- B:** Small lesions in tricky locations
- C:** Lesions near the urethra
- D:** Lesions in the peripheral zone

Question 6: Which type of lesion is most challenging to biopsy during in-bore MRI-guided procedures?

- A:** Plaguelike, thin, and peripheral subcapsular lesion
- B:** Small lesions in the anterior base of a large prostate
- C:** None of the above

Question 7: What advantage does in-bore MRI-guided biopsy offer in scenarios with small lesions in large glands?

- A:** Lower cost
- B:** Ability to visualize and adjust for poor sampling
- C:** Shorter procedure time

Question 8: Which complication may occur due to the trajectory of the needle including the urethra?

- A:** Increased incidence of infection
- B:** Increased incidence of urinary retention
- C:** Greater degree of hematuria and patient discomfort

Patient without a rectum

Question 9: What is one of the challenges of performing in-bore biopsy in patients without a rectum?

- A:** Poor acoustic window in US-guided biopsy
- B:** Difficulty in patient sedation
- C:** High cost of procedure
- D:** Limited availability of MRI-compatible devices

Prostate with unusual morphology

Question 10: Which type of biopsy is considered when there are changes in prostate architecture secondary to previous procedures?

- A:** Transrectal biopsy
- B:** Transperineal biopsy
- C:** In-bore MRI-guided biopsy

THE END



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ANSWER SHEET

A11(25)

Direct MRI-guided In-Bore Targeted Biopsy of the Prostate: A Step-by-Step How To and Lessons Learned

*Time spent on activity											hour										min				
PART 1											PART 2														
	A	B	C	D	E		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E		
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How relevant was the content of this activity to your scope of practice?			
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