MR-US Fusion Prostate Biopsy

SMU-SNU Boramae Medical Center

Myoung Seok Lee

This presentation discusses the role and practical implementation of MRI-targeted prostate biopsy, with a particular focus on MR-US fusion techniques and the complementary role of perilesional biopsy.

Traditionally, prostate biopsy relied on systematic sampling using 10–12 cores, which balanced cancer detection and complication rates. However, recent guidelines, including those from the AUA (2023) and EAU (2024), recommend performing multiparametric MRI (mpMRI) prior to biopsy. MRI enables better identification of clinically significant prostate cancer (csPCa, Gleason grade group ≥2), reduces unnecessary biopsies, and decreases detection of clinically insignificant cancers.

Major trials such as PROMIS, PRECISION, MRI-FIRST, and MULTIPROS have demonstrated that MRI-targeted biopsy improves detection of clinically significant cancers compared to standard transrectal ultrasound (TRUS)-guided systematic biopsy. Combining targeted biopsy with systematic biopsy further increases detection rates. However, the FUTURE trial showed no significant differences in csPCa detection among cognitive fusion, software-assisted fusion, and in-bore MRI-guided biopsy.

Three main approaches to MRI-targeted biopsy are described. In-bore biopsy is performed under direct MRI guidance, offering high accuracy but limited by cost, availability, and long procedure time. Cognitive fusion relies on the operator mentally correlating MRI findings with ultrasound anatomy; it is simple and inexpensive but highly operator-dependent. Software-assisted MR-US fusion biopsy, currently the most widely used method in Korea, integrates MRI and ultrasound images in real time using dedicated hardware and software.

Within software-assisted fusion, two main registration techniques exist: rigid and elastic fusion. Elastic fusion compensates for prostate deformation caused by probe insertion, while rigid fusion assumes no deformation and requires operator adjustment. Although elastic fusion may show slightly better performance, studies report no significant difference in clinically significant cancer detection between the two methods.

Electromagnetic (EM) tracking systems are commonly used for fusion biopsy. These systems consist of a magnetic field generator and position sensors that track the ultrasound probe in real time. The workflow includes MRI data loading, side-by-side display with ultrasound, image alignment, and synchronization of position and angle.

A critical concept in fusion biopsy is plane registration, which ensures that MRI and ultrasound images correspond to the same anatomical plane. This is often performed using sagittal or axial views, referencing structures such as the urethra, verumontanum, or bladder neck. However, in rigid fusion, discrepancies arise because MRI imaging planes and ultrasound beam directions are not parallel.

To address this, X-axis rotation is essential. By rotating MRI images anteriorly or posteriorly, the imaging plane can be aligned more closely with the ultrasound beam trajectory. This adjustment is particularly important for lesions located in the prostate apex or base. Failure to perform appropriate rotation can result in significant localization errors, as demonstrated by cases where incorrect anatomical references led to mistargeted biopsies.

Software-assisted fusion provides several advantages. It increases confidence in lesion localization, corrects cognitive mismatches, and allows targeting of lesions that may be invisible on T2-weighted imaging but visible on diffusion-weighted imaging (DWI). It also improves the accuracy of biopsy for small lesions. However, it can amplify errors if registration is incorrect, emphasizing the need for careful alignment and use of multiple anatomical references.

Perilesional biopsy is introduced as an adjunct to targeted biopsy. It is based on the "penumbra" concept, which defines a region surrounding the MRI-visible lesion where clinically significant cancer is likely to be present. Studies suggest that a substantial proportion of csPCa lies within this surrounding zone, with the radius varying by PI-RADS score.

The role of perilesional biopsy includes compensating for radiology-pathology mismatch, correcting MR-US registration errors, and improving cancer detection rates. Research indicates that combining targeted biopsy with perilesional sampling can achieve detection rates comparable to or better than systematic biopsy, while potentially reducing the number of biopsy cores.

However, perilesional biopsy lacks standardization. Terminology varies widely, including terms such as regional biopsy and zonal biopsy. The number of cores is inconsistent across studies, and definitions of the penumbra differ, ranging from fixed distances to patient-specific approaches based on PI-RADS score and PSA density. Some studies suggest that obtaining at least five cores, including both targeted and perilesional samples, is sufficient to achieve high detection rates of clinically significant cancer.

In summary, MRI-targeted biopsy has become a central approach in prostate cancer diagnosis. Software-assisted MR-US fusion biopsy is the most widely used technique in clinical practice due to its balance of accuracy and practicality. Proper image registration, especially the use of X-axis rotation, is critical for accurate lesion targeting. Perilesional biopsy plays an important complementary role by addressing limitations of targeted biopsy and improving detection of clinically significant cancer, although further standardization is needed.