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TRUS-MRI Fusion Guided Biopsy: Principles and Challenges

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TRUS–MRI fusion guided biopsy has emerged to address limitations of traditional systematic transrectal ultrasound (TRUS) biopsy in prostate cancer detection. While standard TRUS biopsy remains the diagnostic backbone, it can miss up to 30% of clinically significant cancers, especially in large glands or anatomically difficult regions. Multiparametric MRI (mpMRI) improves lesion detection and enables targeted sampling. Among MRI-based approaches, in-bore MRI-guided biopsy offers precise targeting but is resource-intensive, while cognitive targeting is more accessible but operator-dependent. TRUS–MRI fusion combines MRI lesion visualisation with real-time ultrasound guidance, providing a practical balance of accuracy, efficiency, and availability. In this lecture, we will explore the principles and challenges of the fusion method.

The fusion biopsy workflow involves several key steps: mpMRI acquisition and segmentation of the prostate and suspicious lesions, followed by TRUS acquisition and segmentation during the procedure. These datasets are then fused using software algorithms that account for differences in prostate position and deformation. Biopsy is performed with real-time guidance, typically sampling both targeted lesions and systematic cores to maximise detection. Fusion techniques can be broadly divided into cognitive fusion and software-assisted methods, the latter including organ-based, electromagnetic, and mechanical arm tracking systems. Software-assisted approaches reduce operator variability and allow real-time tracking of the biopsy needle, though they require more sophisticated equipment and expertise.

Evidence shows that TRUS–MRI fusion biopsy improves detection of clinically significant prostate cancer, diagnosing up to 30% more high-risk cases compared to systematic biopsy alone. However, combining targeted and systematic biopsies yields the highest sensitivity, as some significant cancers may still be missed with targeted sampling alone. Looking ahead, advances such as automated segmentation, motion correction, and adjunct ultrasound techniques may further enhance accuracy, while decreasing costs could broaden accessibility, solidifying fusion biopsy as a key component of prostate cancer diagnosis.

Keywords: *Prostate cancer, Fusion biopsy, Techniques, Clinically significant cancer, Magnetic resonance imaging, Transrectal ultrasound, Principles, Challenges*