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# Magnetic resonance-ultrasound fusion prostate biopsy in the diagnosis of prostate cancer

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**Abstract**

The advent of multiparametric magnetic resonance imaging (MRI) has ushered in a new era for urologists who perform prostate needle biopsies. The fusion of MRI with transrectal ultrasound (US) allows the direct targeting of suspicious lesions, which has been shown to improve the performance of conventional random biopsy techniques by increasing detection of clinically relevant disease while also decreasing detection of low-risk cancer. However, as with any new technology, many questions regarding effectiveness, reproducibility, and generalizability still remain. In this review, we (1) provide a summary of the various sequences that comprise a MRI of the prostate; (2) evaluate the 3 different ways of incorporating MRI into targeted biopsies of the prostate including in-bore MRI-guided biopsy, cognitive fusion, and device-mediated fusion; (3) review the sensitivity of MR-US fusion in the detection of clinically significant and clinically insignificant disease; and (4) review the barriers to the widespread implementation of MR-US fusion into everyday practice. Whereas other articles in this issue of *Urologic Oncology Seminars* will discuss other aspects of MRI in the management of prostate cancer, the purpose of this article is to provide an overview of MR-US fusion biopsies in the diagnosis of prostate cancer. 

*Keywords:* Magnetic Resonance Imaging; Ultrasound; Fusion; Prostate Biopsy; Prostate Cancer

## Introduction

With an estimated 1.1 million incident cases in 2012, prostate cancer constitutes 15% of all new cancers diagnosed among men worldwide [1]. Efforts to accurately diagnose clinically relevant prostate cancer early in the disease course has been a public health priority since the introduction of prostate-specific antigen (PSA) in the 1980s. However, the gold standard diagnostic test for an elevated PSA—the extended sextant transrectal ultrasound (TRUS)-guided prostate needle biopsy—has significant clinical deficiencies [2,3]. Although TRUS-guided prostate biopsies initially represented a major advancement over older methods in which biopsy needles were guided only by the examiner's finger, the TRUS technique is nontargeted and prone to sampling error. As a result, TRUS biopsies detect many cancers that do not require treatment and, more importantly, fail to diagnose many cancers that do [4–6].

In an effort to improve the performance of TRUS-guided prostate biopsies, several commercially available solutions have been introduced to the marketplace over the last decade. One solution that has garnered significant momentum has been the incorporation of prostate MRI into the prostate biopsy armamentarium. Compared to TRUS, multiparametric MRI (mpMRI) has better image resolution, superior visualization of anatomical structures, the capacity for functional assessment, and the ability to assess tumor aggressiveness [7–10]. As a result, MR-US fusion biopsy systems combine the powerful ability of MRI to visualize clinically relevant prostate cancer with sophisticated probe-tracking software to substantially improve the prostate biopsy technique. In this narrative review, we focus on

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the fundamentals of MR-US fusion technology, including the basic tenets of mpMRI, cognitive fusion, and MR-US fusion devices. We provide a discussion regarding the sensitivity of MR-US fusion in the detection of clinically significant and clinically insignificant disease and conclude with a review of the potential barriers to the widespread adoption of MR-US fusion into everyday practice.

## Multiparametric magnetic resonance imaging

Hricak et al. [11] was the first to describe the features of prostate cancer on MRI. Using a 0.35-T magnet, the authors described malignant prostate tissues as having a higher intensity signal than surrounding benign tissues. Since then, a litany of advancements in MRI technology has improved the ability of MRI to localize prostate cancer in vivo. Prostate mp-MRIs incorporate a combination of high-resolution T2-weighted images with various functional techniques such as diffusion-weighted imaging (DWI), dynamic contrast enhancement (DCE), and MR-spectroscopic (MRS) imaging. The relative clinical value of each component differs and is summarized below.

### *T2-weighted imaging*

T2-weighted imaging (T2WI), which reflects the tissue water content, provides the best depiction of prostate zonal anatomy and superior tissue contrast for the detection, localization, and staging of prostate cancer [12]. On T2WI, prostate cancer classically manifests as a round or ill-defined, low-signal intensity focus in the peripheral zone. However, this is a very nonspecific finding as myriad conditions such as prostate intra-epithelial neoplasia, prostatitis, hemorrhage, atrophy, scars, and posttreatment changes can mimic cancer on T2WI [13]. Furthermore, lesion detection is especially problematic in the transition zone because benign prostate hyperplasia can mimic the appearance of cancer [14,15]. Similarly, biopsy-related hemorrhage can cause artifacts that resemble the appearance of cancer, thus the time interval between the biopsy and the prostate MRI should be at least 4 to 6 weeks [9]. In our center, we commonly wait 3 months or more. Because of potential false positives, T2WI alone is not recommended as functional parameters, discussed below, improve both the sensitivity and specificity of T2WI (which alone is only 74% and 88%, respectively) [16].

### *Functional parameters*

DWI is a form of MRI that is based upon measuring random Brownian motion of water molecules within tissue [17]. Generally, dense cellular tissues exhibit lower diffusion coefficients and thus diffusion is particularly useful in tumor characterization. The slope of change of the signal, established by the degree of diffusion weighting, is known as the apparent diffusion coefficient (ADC) and generates quantitative maps of molecular mobility. Prostate cancer typically displays high signal intensity on DWI and low values/darkness on ADC maps [18–20], which dramatically improves the specificity of prostate cancer detection compared to T2WI alone [21]. Furthermore, ADC values have been shown to correlate with Gleason scores making DWI a potent clinical tool and an essential parameter for all prostate mp-MRIs [22–25].

Another functional parameter that can improve the performance of T2WI in the detection of prostate cancer is DCE. DCE is performed following the administration of gadolinium-based contrast medium and is the most reliable method for evaluating tumor vascularity [26]. Similar to other functional techniques, DCE significantly improves both the sensitivity and specificity of prostate mpMRI [27]. However, because normal prostate tissue is highly vascular, a pregadolium and postgadolinium comparison is usually inadequate to detect prostate cancer without T2WI and DWI [28,29]. In general, use of DCE in the detection of prostate cancer has demonstrated favorable performance characteristics [27] and, although the literature is sparse, DCE may also have an emerging role in the evaluation of postprostatectomy and postradiotherapy recurrences [30–33].

MRS enables the detection of the lower levels of citrate and higher levels of choline in prostate cancer tumors compared to benign tissue [34]. MRS can be used to predict the presence or absence of cancer and provide information about the aggressiveness of the disease, but does not give staging information owing to poor spatial resolution [35]. Furthermore, it requires a high level of additional expertise, an endorectal coil (ERC) at 1.5 T, and adds time to the examination [13]. Because of these factors, the decision to include MRS in a prostate MRI depends more on local expertise and availability. The Figure demonstrates T2WI, DWI, ADC maps, and DCE imaging.

### *Prostate imaging-reporting and data system*

Prostate Imaging-Reporting and Data System(PI-RADS) Version 2 was developed by members of the PI-RADS Steering Committee, several working groups with international representation, and administrative support from the American College of Radiology (ACR) using the best available evidence and expert consensus opinion. Its adoption is designed to promote global standardization and diminish variation in the acquisition, interpretation, and reporting of prostate mpMRI examinations. A comprehensive discussion about PI-RADS is beyond the scope of this article but it can be readily assessed on the ACR website [36].

### *Salient features of PI-RADS*

(1) PI-RADS is a system for rating the likelihood of significant cancer in each region of interest, ranging from 1 (very low) to 5 (very high).