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Review Article

Prostate MRI for brachytherapists: Diagnosis, imaging pitfalls, and post-therapy assessment

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ABSTRACT Optimal integration of multiparametric MRI (mp MRI) into prostate brachytherapy practice necessitates an understanding of imaging findings pertinent to prostate cancer detection and staging. This review will summarize prostate cancer imaging findings and tumor staging on mp MRI, including an overview of the Prostate Imaging Reporting and Data System (PIRADS)—structured reporting schema, mp MRI findings observed in the post-therapy setting including cases of post-treatment recurrence, and MRI concepts integral to successful salvage brachytherapy.

Keywords: Anatomy; Prostate; Prostate cancer; Brachytherapy; MRI; Multiparametric MRI

Introduction

In addition to understanding of multiparametric MRI (mp MRI) technique and normal prostate anatomy on MRI, it is important for the brachytherapist to become familiar with those mp MRI findings integral to prostate cancer (PCa) detection and staging. mp MRI enables superior delineation of prostate volume and the dominant index lesion, critical for most prostate interventions. Familiarity with the Prostate Imaging Reporting and Data System (PIRADS)—structured reporting schema is also valuable, as this schema is used increasingly in diagnostic radiology reports. Also, essential is an understanding of the expected mp MRI findings observed in the post-therapy setting, findings associated post-treatment recurrence, and MRI concepts pertinent to successful salvage brachytherapy (BT). A comprehensive summary of these concepts is presented in this review, alongside several mp MRI imaging examples.

PCa appearance and diagnostic pitfalls on mp MRI

PCa histologic features pertinent to mp MRI include its relatively increased cellular density compared to normal prostate tissue, with a relative reduction in luminal volume, extracellular space, and increased tumor vascularity due to neoangiogenesis (1—4). As a result, PCa, irrespective of its location within the gland, will typically present as either well-defined hypointense foci or more subtle slightly hypointense foci on T2-weighted imaging, which correspond to areas of restricted diffusion, that are hyperintense on diffusion weighted imaging (DWI) with corresponding reduced apparent diffusion coefficient (ADC) values. On dynamic contrast enhanced (DCE) images, foci of cancer are associated with focal, early rapid, and high peak enhancement, with a relatively rapid washout of contrast as compared to the surrounding prostate tissue.

Once a focal lesion is detected, an evaluation of the clinical stage of the tumor is required. The most important overall assessment is whether the tumor is confined to the gland (T stage $\leq$ 2) or extends beyond the prostate gland ($\geq$T3). The high spatial resolution and delineation of the prostate capsule allow for assessments of extracapsular extension (ECE) and neurovascular bundle invasion. These along with assessments of seminal vesicle invasion are critical diagnostic staging criteria (5). The typical appearance for an organ confined peripheral zone PCa is illustrated in Figs. 1a and 1b, along with examples of ECE with seminal

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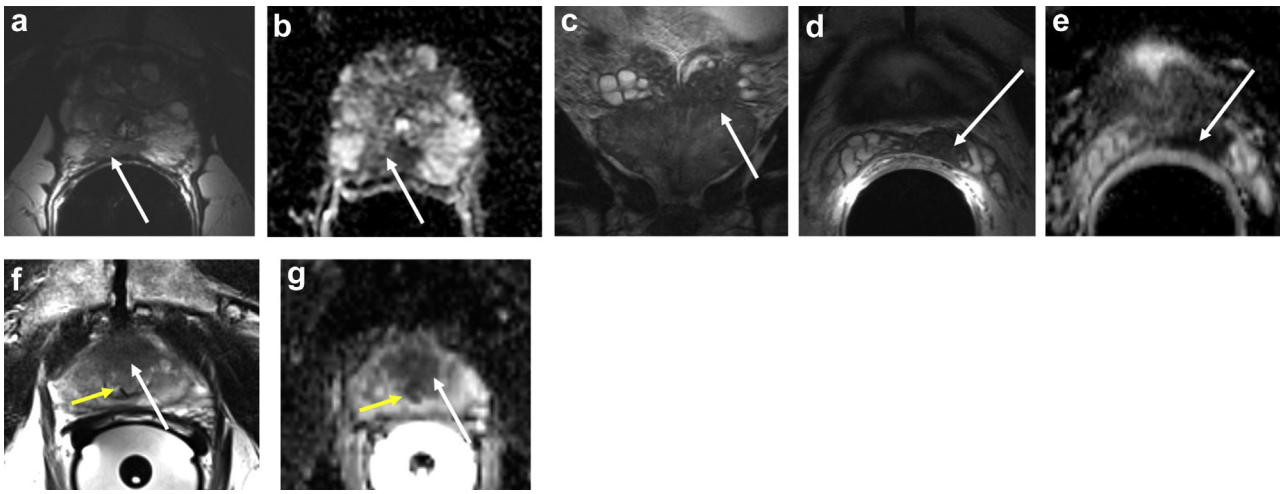

Fig. 1. Prostate cancer tumor extension delineated on MRI. (a) and (b): axial T2-weighted images (a) and apparent diffusion coefficient (ADC) maps (b) of the prostate demonstrate an area of T2 hypointensity and restricted diffusion centered within the right peripheral zone at the level of the midgland, consistent with organ confined disease (white arrows). (c)–(e): coronal (c) and axial (d) T2-weighted images and axial ADC maps (e) of the prostate and seminal vesicles demonstrate T2 hypointense diffuse tumor involving the right and left gland from apex to base, including extracapsular extension and left seminal vesicle invasion (white arrows). (f) and (g): axial T2-weighted images (f) and ADC maps (g) of the prostate demonstrate an area of T2 hypointensity and restricted diffusion within the anterior peripheral zone, consistent with distal apical tumor (white arrows) with urethral involvement (yellow arrow).

vesicle invasion (Figs. 1c–1e), and distal apical tumor with urethral involvement (Figs. 1f and 1g).

There exist several imaging interpretive pitfalls in the detection and local staging of PCa with mp MRI, and the readers are encouraged to consult recent reviews on the subject (4, 6, 7). Among the prostate mp MRI interpretive pitfalls, several of the more common may be subdivided into normal anatomic structures that can mimic tumor, noncancerous conditions that can simulate focal lesions, common anatomic "blind spots," and technical challenges related to imaging acquisition (4).

Normal anatomic structures that can mimic prostate malignancy include the central zone (CZ), anterior fibromuscular stroma (AFMS), stromal benign prostatic hypertrophy (BPH) nodules, and the surgical capsule, when asymmetric thickening of the surgical capsule is present. Normal CZ demonstrates relatively reduced T2 intensity and restricted ADC values compared to the PZ and, as a result, may be mistaken for a tumor extending from either the PZ or TZ at the base of the prostate (4). Less than 5% of PCas arise from the CZ, but as these are typically more aggressive than PZ tumors, their detection is not without consequence. Correct identification of this structure is achieved by identifying the symmetry of the normal CZ, its sharp margins, classic location surrounding the ejaculatory ducts, and homogenous low-signal intensity, in contrast to the ill-defined borders and asymmetric appearance typical for CZ cancers (2, 4, 7, 8). The surgical capsule, an important urologic landmark for transurethral resection of the prostate for BPH, normally surrounds the TZ as a band-like structure with relative low signal on T2-weighted imaging and ADC. Occasionally, asymmetric thickening of this structure may be read as an area of focally restricted diffusion within the PZ or TZ. In this case, correlating this finding to the course of the normal surgical capsule, as seen on T2-weighted images, can minimize diagnostic error (4, 7, 9). The AFMS, located anterior to the TZ, is another structure whose normal T2 hypointensity and reduced ADC signal, similar to that of PCa, can confound accurate diagnosis. Normal AFMS will have normal DWI/ADC signal, however, in contrast to the restricted diffusion seen in PCa. Its typical hypovascularity on DCE, as compared to the expected hyperenhancement of focal PCas, is another helpful discriminating feature (3, 7, 10, 11). Distinguishing a stromal BPH nodule from TZ cancer can be challenging. PCas arising in the TZ constitute approximately 30% of all PCas but are commonly missed with standard transrectal ultrasound–guided biopsy. Their detection can also be confounded by changes of BPH, which can result in marked heterogeneity of transition zone signal on T2-weighted images. There is a known overlap in T2 signal intensity, ADC values, and DCE K_{trans} values between stromal BPH nodules and TZ cancers (6, 12, 13). Some groups have suggested that ultra-high b-value DWI may have superior diagnostic performance in distinguishing TZ cancers (6, 13). Evaluation of lesion shape and margins can also improve diagnostic confidence in this setting. Stromal BPH nodules typically have a rounded shape and discrete margin, often with a well-demarcated pseudocapsule, as compared to the more lenticular and/or teardrop shape and ill-defined margins of TZ cancers, which has been termed the "erased charcoal sign" (Fig. 2). Extension into the AFMS or PZ by TZ cancers is also a distinguishing feature (6, 7).

Among the noncancerous conditions that can mimic focal lesions, acute and chronic prostatitis, particularly