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Prostate MRI for brachytherapists: Anatomy and technique

A.M. Venkatesan[1,*], R.J. Stafford[2], C. Duran[1], P.D. Soni[3], A. Berlin[4], P.W. McLaughlin[3]

[1]Section of Abdominal Imaging, Department of Diagnostic Radiology, MD Anderson Cancer Center, Houston, TX
[2]Department of Imaging Physics, MD Anderson Cancer Center, Houston, TX
[3]Department of Radiation Oncology, University of Michigan, Novi, MI
[4]Department of Radiation Oncology, Princess Margaret Cancer Centre, Toronto, ON

ABSTRACT

PURPOSE: To present an overview of mp MRI techniques necessary for high-resolution imaging of prostate.

METHODS: We summarize examples from our clinical experience and concepts from the current literature that illustrate normal prostate anatomy on multiparametric MRI (mp MRI).

RESULTS: Our experience regarding optimal mp MRI image acquisition is provided, as well as a summary of prostate and periprostatic anatomy and anatomical variants that pose challenges for BT.

CONCLUSIONS: mp MRI provides unparalleled assessment of the prostate and periprostatic anatomy, making it the most appropriate imaging modality to facilitate prostate BT treatment planning, implantation, and followup. This work provides an introduction to prostate mp MR imaging, anatomy, and anatomical variants essential for successful integration mp MRI into prostate brachytherapy practice.

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

Introduction

Prostate cancer (PCa) remains the most common noncutaneous malignancy detected in North American and European men and the second most common cause of cancer-related death. Brachytherapy (BT) represents an efficacious, well-tolerated, and cost-effective treatment for patients with clinically localized disease (1, 2). In fact, evidence strongly suggest that prostate BT as definitive treatment or as a boost to external beam radiotherapy is associated with excellent local control, biochemical disease-free survival, and is related with an excellent post-treatment health-related quality of life making it a mainstream therapeutic option for low- to-intermediate-risk disease (1,3−7). Both low−dose-rate and high−dose-rate BT represent accurate and successful methods for delivering ablative doses of radiation to the prostate with high degrees of precision and conformality. Over the past several years, due to biologic and intrinsic technical considerations, there is increasing interest and migration toward high-dose rate−based treatments (8−10). With the maturation of prostate BT planning and delivery techniques, the clinical goals of optimal therapy have evolved. These now include not only local disease control and increased survival but also the minimization of treatment-related adverse events and side effects as patients, living longer, may need to cope with treatment-related sequelae for the rest of their lifetime (7).

Critical to achieving optimal prostate BT outcomes is a thorough understanding of prostate anatomy and the MRI techniques necessary to adequately delineate this anatomy. Multiparametric MRI (mp MRI), a combination of anatomical and functional MR-imaging sequences, offers high-resolution imaging of the prostate and periprostatic anatomy compared with ultrasound (US) or computed tomography (CT). This makes it the ideal imaging modality to facilitate tumor identification and prostate BT treatment planning, implantation, and followup (Fig. 1). To leverage mp MRI for optimal prostate BT, knowledge of how mp MRI is acquired, the utility of the individual sequences and an awareness of normal prostate and periprostatic MR anatomy are critical. A comprehensive summary of

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* Corresponding author. Director of Translational Research, Section of Abdominal Imaging, MD Anderson Cancer Center, 1400 Pressler St., Unit 1473, Houston, TX 77030. Tel: 713-563-8880; fax: 713-794-4379.

E-mail address: avenkatesan@mdanderson.org (A.M. Venkatesan).

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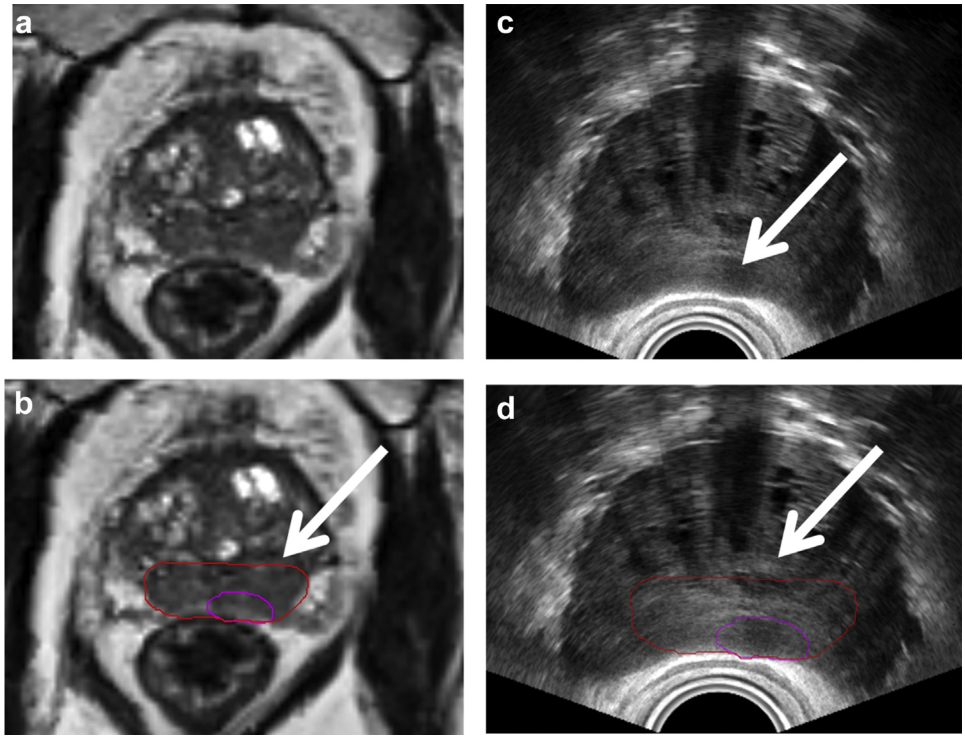

Fig. 1. MRI vs US for tumor delineation and radiation treatment planning. Axial T2-weighted MRI of the prostate (a) depicts a T2 hypointense tumor in the right and left peripheral zone at the apex. Co-registered transverse ultrasound images (c) show a left posterior hypoechoic nodule which corresponds to the tumor seen on MRI (white arrow). MRI allows accurate delineation of the GTV (red contour), which is underestimated by the US-defined GTV (magenta contour, white arrow)) (d). US fails to depict prostate zonal anatomy nor complete extent of tumor. As a result, contouring of the entire GTV on US (white arrow) is a visual approximation (d). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.) GTV = gross tumor volume; US = ultrasound.

these concepts is presented in this review, alongside several mp MRI imaging examples.

mp MRI technique: coil technology and imaging sequences

The multiparametric aspect of mp MRI refers to the inclusion of pulse sequences that provide both morphologic and functional information about the prostate for tumor detection and staging. Standard prostate mp MRI technique includes both anatomical T1- and T2-weighted images and the use of functional imaging sequences, that is, diffusion-weighted imaging (DWI), dynamic contrast-enhanced (DCE) imaging, and in some instances, MR spectroscopic imaging (MRSI) (11). Mp MRI affords superior spatial and soft-tissue contrast resolution compared with other prostate imaging techniques, such as US and CT. High–field strength (3 T) magnets and dedicated (e.g. endorectal) coil designs have helped to enable higher imaging signal-to-noise ratios (SNR), which can be further leveraged to increase image resolution, contrast, and/or improve acquisition times (11).

Both 1.5 and 3 T MRI are used for diagnostic prostate MRI, with 3 T magnets generally preferred given their higher relative SNR. This yields higher resolution detail of the normal prostate and periprostatic anatomy and *in situ* tumors, although higher field strength imaging is generally more susceptibility to image artifacts such as from motion or signal losses from susceptibility. Current imaging technique involves the use of pelvic phased-array coils with or without the addition of a rigid or inflatable endorectal coil (ERC); inflatable coils are equipped with a balloon filled with ~50 mL or more of air or liquid perfluorocarbon for reduced susceptibility effects (12). ERC use improves the SNR by approximately an order of magnitude and enables use of small fields of view imaging, which is necessary for tumor detection and local staging (12–15) (Fig. 2). Thus, ERC use is favored for diagnostic prostate MRI, although it adds to discomfort, time, and costs. At one of the author institutions (AMV, RJS, CD), prostate mp MRI is performed with a combination of torso array, pelvic, and ERC, with 1 mg glucagon administered immediately after coil insertion to reduce bowel peristalsis- and motion-related artifacts. Recent studies have suggested that 3 T field strength without ERC use may offer adequate image quality for visualization of prostate and surrounding anatomy, with a high rate of identification of clinically significant PCas (16–20). These data are compelling from the perspective of mitigating patient discomfort, scan duration, and cost. Efforts to optimize 3T prostate mp MRI without an ERC remain