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MRI in prostate brachytherapy: Evidence, clinical end points to data, and direction forward

Thomas J. Pugh*, Sajal S. Pokharel

Radiology, University of Colorado, Aurora, CO

ABSTRACT The integration of multiparametric MRI into prostate brachytherapy has become a subject of interest over the past 2 decades. MRI directed high-dose-rate and low-dose-rate prostate brachytherapy offers the potential to improve treatment accuracy and standardize postprocedure quality. This article reviews the evidence to date on MRI utilization in prostate brachytherapy and postulates future pathways for MRI integration. © 2016 American Brachytherapy Society. Published by Elsevier Inc. All rights reserved.

Keywords: MRI; Prostate; Brachytherapy; LDR; HDR

Introduction

Multiparametric MRI allows for identification of prostate cancer lesions (1, 2), fosters estimates of pathologic organ confinement (3−5), and enhances radiation treatment planning (6). Standard workflow for prostate brachytherapy has historically included CT and/or transrectal ultrasound (TRUS). However, there are several advantages to MRI integration including superior intraprostatic soft tissue resolution, localization of the dominant intraprostatic lesion, and improved anatomic visualization of the prostate apex, prostate-bladder interface, prostate-rectal interface, neurovascular bundles, and genitourinary diaphragm (Fig. 1). Despite the apparent advantages attributable to superior target and organ-at-risk delineation, routine integration of MRI into prostate brachytherapy workflow has not been widely adopted. There are multiple reasons for this lack of consensus including poor access to advanced technology/necessary supportive resources, economic considerations such as cost containment or imaging reimbursement, and the generally favorable results achieved without MRI integration. The purpose of this article is to review the current body of evidence regarding MRI utilization in prostate brachytherapy.

The process of prostate brachytherapy

Generally speaking, optimal prostate brachytherapy adheres to a six-step process: (*1*) effective patient selection, (*2*) treatment simulation, (*3*) treatment plan fabrication, (*4*) treatment delivery (implant), (*5*) postimplant dosimetry/quality assurance (low dose rate [LDR]), and (*6*) posttreatment response assessment/surveillance.

MRI for prostate brachytherapy patient selection

The current evidence supporting MRI for prostate brachytherapy patient selection can be divided into two categories: consideration for focal brachytherapy (covered elsewhere in this issue of *Brachytherapy*) and estimation of extraprostatic disease extension (EPE). The unique physical properties attributed to prostate brachytherapy allow for high-dose radiation treatment to the prostate while minimizing radiation exposure to the surrounding tissue. Patient selection for prostate brachytherapy as a single modality treatment is typically limited to patients at relatively low risk of extraprostatic extension as defined by Partin tables (7) or other risk stratification tools. The rationale for this convention is based on results suggesting that prostate-only treatments are suboptimal in those men at higher risk of pathologic EPE (8−10); implying the rapid dose falloff with distance from the radiation source achievable with brachytherapy may in fact be detrimental in these situations and may be attributable to underdosing of disease extension beyond the margin of effective dose. Therefore, accurate estimation of EPE seems to be a critical component of patient selection for prostate brachytherapy. Recent clinical

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* Corresponding author. Radiation Oncology, University of Colorado, 1665 Aurora Ct, Suite 1032, Aurora, CO 80045. Tel.: 7208480143; fax: 7208480238.

E-mail address: thomas.pugh@ucdenver.edu (T.J. Pugh).

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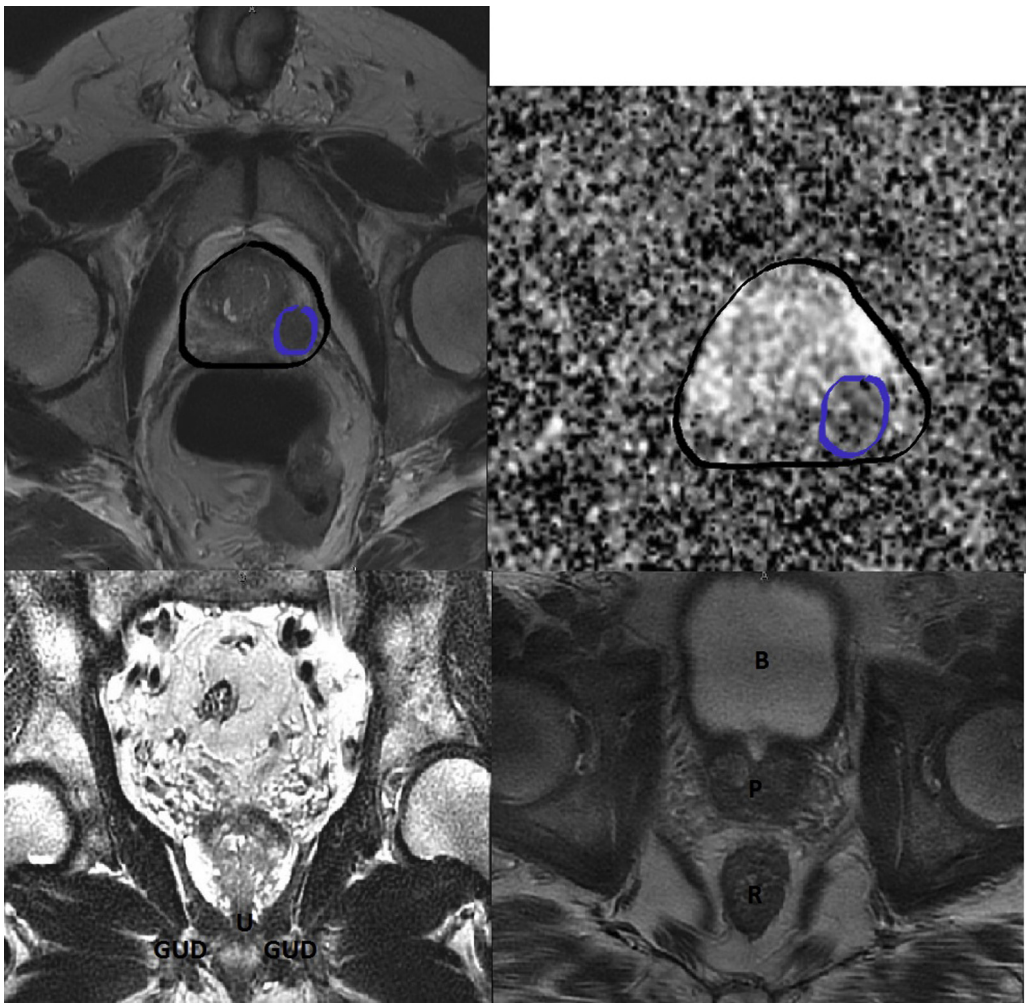

Fig. 1. Multiparametric MRIs of the prostate showing: (a/b) soft tissue resolution of the prostate gland (outlined in black) with a dominant lesion in the left peripheral zone (outlined in blue) on T2-weighted axial (a) and diffusion-weighted (b) series. (c) Identification of the urethra (U) and genitourinary diaphragm (GUD) on T2-weighted coronal series. (d) Identification of the rectum (R) and urinary bladder (B) at the level of bladder neck entry into the prostate gland (P). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

studies have validated the predictive value of MRI for both EPE estimation and identification of clinically significant organ confined prostate cancer. Furthermore, results from a recent clinical trial suggest that MRI may outperform conventional methods based on known prognostic variables (digital rectal examination, prostate-specific antigen, Gleason score) and random TRUS biopsy (11).

Although the evidence is robust regarding MRI as a cancer detection and clinical staging tool, data correlating MRI with clinical outcome after treatment and/or modality selection is lacking. Pugh *et al.* (3) reported a pathologic correlative analysis on 171 men with clinical stage T1c–T2c by digital rectal examination, Gleason score 7, and prostate-specific antigen <10 ng/mL who underwent radical prostatectomy after a preoperative MRI within the context of patient selection for prostate brachytherapy. Clinical T-stage and MRI were predictive of pathologic EPE. Furthermore, MRI test performance improved with increasing EPE distance. These investigators concluded that MRI may be useful in patient selection for prostate brachytherapy monotherapy; however, the narrow demographic analyzed limits widespread generalizability.

MRI simulation and treatment plan fabrication

The concept of MRI-guided prostate brachytherapy spans the past several decades. An intraoperative, MRI-guided technique for LDR prostate brachytherapy was originally investigated using a 0.5 T open MRI unit (12). Of those men treated with MRI-guided brachytherapy monotherapy targeting the peripheral zone, the 4-year estimate of rectal bleeding requiring coagulation therapy was 8% and no patient demonstrated radiation cystitis or urethral stricture (13). Furthermore, the acute toxicity profile of this approach appeared favorable compared to TRUS-guided prostate brachytherapy (14, 15). Biochemical control outcomes were variable with men classified as low risk

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