Clinical Radiology xxx (2017) 1–15

Contents lists available at ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

Review

Prostate cancer: state of the art imaging and focal treatment

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ARTICLE INFORMATION

Article history:
Received 14 November 2016
Received in revised form
26 January 2017
Accepted 7 February 2017

In 2016, it is estimated 180,890 men are newly diagnosed with prostate cancer and 3,306,760 men live with prostate cancer in the United States. The introduction of multiparametric (mp) magnetic resonance imaging (MRI) of the prostate, standardised interpretation guidelines such as Prostate Imaging Reporting and Data System (PI-RADS version 2), and MRI-based targeted biopsy has improved detection of clinically significant prostate cancer. Accurate risk stratification (Gleason grade/score and tumour stage) using imaging and image-guided targeted biopsy has become critical for the management of patients with prostate cancer. Recent advances in MRI-guided minimally invasive ablative treatment (MIAT) utilising cryoablation, laser ablation, high-intensity focused ultrasound ablation, have allowed accurate focal or regional delivery of optimal thermal energy to the biopsy proven, MRI-detected tumour, under real-time or near simultaneous MRI monitoring of the ablation zone. A contemporary review on prostate mpMRI, MRI-based targeted biopsy, and MRI-guided ablation techniques is presented.

Introduction

The American Cancer Society (ACS) estimates that there are 3,306,760 people living with prostate cancer in the United States and 180,890 new cases of prostate cancer will be diagnosed.[1] In 2016 prostate cancer was the most commonly diagnosed non-cutaneous cancer and second-leading cause of death in men.[2] With the dramatic increase in good-quality diagnostic multiparametric (mp) magnetic resonance imaging (MRI), organ-confined prostate cancer is increasingly visible, targetable, and potentially treatable with focal ablative technologies.[1,3,4]

Unfortunately, the timeline and variability of prostate cancer progression from organ-confined disease to extra-prostatic spread is unknown; however, it seems intuitive that early detection and proper characterisation may play a role in preventing the development of metastatic disease.[5] In view of the significant disparity on recommendations for early detection and prostate cancer screening among various scientific organisations (American Urological Association, American Society of Clinical Oncology, National Comprehensive Cancer Network, American Cancer Society, US Preventative Task Force and the European Association of Urology), and the uncertainty of the harm versus benefit of screening, this review will not delve into this controversy. Our focus will be on the current state of the art of prostate imaging, biopsy, and ablation techniques.

The significance of precise image identification and biopsy is further amplified by level 1 evidence supporting

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http://dx.doi.org/10.1016/j.crad.2017.02.010
0009-9260/

detection and subsequent aggressive treatment of intermediate and high-risk prostate cancer.[6] Therefore, accurate ascription of cancer risk (i.e., grade and stage) using imaging and biopsy is critical. Advances in prostate treatment have become integrated with imaging, image identification, and image guided biopsy, and therapy propelling prostate treatment solutions forward faster than ever.

Importance of MRI for prostate imaging

Native prostate cancer

Prostate cancer has traditionally been diagnosed by prostate-specific antigen (PSA) screening and digital rectal examination (DRE) followed by DRE-directed biopsy. Use of ultrasound imaging has helped direct the biopsies further but has fallen short of being sensitive enough to find all the prostate cancer within the gland. Furthermore, systematic (non-targeted) sampling the entire organ has provided some answers but may also miss or under-sample small volume, but clinically significant disease, which may result in delayed diagnosis and treatment.

MRI is the best imaging method of the prostate and periprostatic structures because MRI provides superior soft-tissue contrast resolution, high spatial resolution, multiplanar imaging capabilities, and a field of view larger than transrectal ultrasound. The use of integrated endorectal and pelvic phased-array coils has led to improved visualisation of the prostatic fossa. T2-weighted imaging (WI) is sensitive in depicting prostate cancer; however, decreased T2 signal intensity is not specific for prostate cancer and can be seen in benign conditions. Functional parametric imaging including dynamic contrast-enhanced imaging (DCEI), diffusion-weighted imaging (DWI), and MRI spectroscopic imaging (MRSI) complement morphological MRI by reflecting perfusion characteristics, Brownian motion of water molecules, and metabolic profiles, respectively. Significant inverse correlation was shown between the apparent diffusion coefficient (ADC) value and Gleason score/highest grade.[7] A combination of T2WI, DWI and DCEI with or without MRSI, is referred to as mpMRI. The introduction and maturation of mpMRI now allows for imaging-based identification of prostate cancer, which may improve diagnostic accuracy for higher-risk tumours.[8]

In 2015, a consensus panel agreed to Prostate Imaging–Reporting and Data System (PI-RADS) version 2, which promoted standardised MRI acquisition and interpretation to improve detection, localisation, characterisation, and risk stratification of clinically significant prostate cancer in treatment naive prostate glands.[9] Targeted biopsy of suspected cancer lesions detected by MRI is associated with increased detection of high-risk prostate cancer and decreased detection of low-risk prostate cancer particularly with the aid of MRI/ultrasound fusion platforms.[10] The use of mpMRI has expanded beyond staging to detection, characterisation, monitoring for active surveillance, and cases of suspected recurrence after failed definitive therapy (Fig 1 a–d).

The use of MRI for recurrent prostate cancer continues to evolve and has potential to evaluate both local recurrence and distant bony and nodal metastases.[11] In 2013, a consensus panel chaired by Professor Michael Marberger endorsed utilisation mpMRI to identify patients for focal therapy.[12] mpMRI is capable of localising small tumours for focal therapy. Although mpMRI plays an established, critical role in native and recurrent prostate cancer imaging, functional, metabolic imaging for prostate cancer is in its formative years. ^{11}C-choline positron-emission tomography (PET)/computed tomography (CT) has an advantage to reveal both local recurrent and distant metastatic prostate cancers. ^{11}C-choline PET/CT had a sensitivity of 73%, a specificity of 88%, a positive predictive value (PPV) of 92%, a negative predictive value (NPV) of 61%, and an accuracy of 78% for the detection of clinically suspected recurrent prostate cancer in postsurgical patients.[13] In a study of post-prostatectomy patients with rising PSA, mpMRI is superior for the detection of local recurrence, ^{11}C-choline PET/CT is superior for pelvic nodal metastasis, and both are equally excellent for pelvic bone metastasis. ^{11}C-choline PET/CT and mpMRI are complementary for restaging prostatectomy patients with suspected recurrent disease and exhibit diverse patterns of recurrence with implications for optimal salvage treatment strategies.[11,14] Furthermore, new readily available PET agents including ^{68}Ga-prostate-specific membrane antigen (PSMA) indicate favourable sensitivity and specificity profiles compared to choline-based PET imaging techniques.[15] Additionally, a recent publication demonstrated that late 3 hour imaging of ^{68}Ga-PSMA helped to clarify activity within the prostate due to decreased activity within the bladder at this time point.[16] Early work with simultaneous MRI/PET shows promise in capitalising both the functional aspects of PET with the superb anatomical capabilities of MRI.[17]

With the limitations of ultrasound and PET/CT, MRI remains pre-eminent for the detection and staging of prostate tumours within the pelvis. MRI provides superior soft-tissue contrast resolution, high spatial resolution, direct multiplanar imaging capabilities, and a large field of view.

Recurrent prostate cancer

After a definitive radical prostatectomy, patients are followed at periodic intervals with measurement of serum PSA and DRE; however, DRE is frequently unreliable in evaluating local recurrent disease after radical prostatectomy. Following radical prostatectomy, PSA levels are expected to be undetectable within several weeks of surgery. If there is a rise in a previously undetectable or stable postoperative PSA level (biochemical failure), a prompt search for persistent, recurrent, or metastatic disease should be pursued; however, PSA alone does not differentiate local from distant disease recurrence. There are three main categories of recurrence after radical prostatectomy for prostate cancer: (1) local recurrence in the prostatic bed, (2) distant metastasis (e.g., bone, lymph node), and (3) a combination of local recurrence and distant metastasis. Therefore, the major objective of diagnostic imaging studies

Please cite this article in press as: Woodrum DA, et al., Prostate cancer: state of the art imaging and focal treatment, Clinical Radiology (2017), http://dx.doi.org/10.1016/j.crad.2017.02.010