Chapter 2

Advances in Medical Imaging Technology for Accurate Detection of Prostate Cancer

Alireza Ziaei

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Abstract

Prostate cancer (PCa) is the most frequently diagnosed non-cutaneous male malignancy and one of the leading causes of cancer-related mortality in the United States. Biologic heterogeneity of PCa results is different presentations ranging from indolent to highly aggressive tumors with high morbidity and mortality. Due to this broad range of clinical behavior, it is required to differentiate clinically significant PCa (csPCa) tumors and reduce detection of indolent cancers. PCa is generally diagnosed with non-targeted systematic trans-rectal ultrasound (TRUS)-guided biopsy in patients with elevated prostate serum antigen (PSA) or abnormal digital rectal examination (DRE). Non-targeted systematic TRUS as the typical imaging modality for assessing the prostate, samples only a small part of the gland with a high possibly that the biopsy results may not catch the most aggressive tumor in the gland accurately. Multi-parametric (MP) magnetic resonance imaging (MRI), as the most specific and sensitive imaging modality in PCa management, has been reported to be the reference standard for prostate imaging endorsed. However, there are a variety of interpretive pitfalls, which have been reported to be encountered at mpMRI of the prostate. The purpose of this chapter is to provide a summary of the current advances in accurate detection of PCa.

Keywords: prostate cancer (PCa), prostate specific antigen, digital rectal exam, trans-rectal ultrasound guided biopsy (TRUSgBX), Gleason scores, multi-parametric (MP) magnetic resonance imaging (MRI)

1. Introduction

Prostate cancer (PCa) is the most frequently diagnosed non-cutaneous male malignancy and one of the leading causes of cancer-related mortality in the United States [1–3]. PCa is a disease

of increasing significance in the world. Even though PCa may be less common in many developing countries, but its incidence and mortality rate has been raised [4]. The incidence of PCa influenced by the diagnostic efforts and the mortalities reported for any specific geographic region depending on the reliability of cancer detected [5]. The range of the five-year survival rate varies from 29% in patients with metastatic PCa to 100% in patients with localized disease [6, 7]. Biologic heterogeneity of PCa results is different presentations ranging from indolent to highly aggressive tumors with high morbidity and mortality [8] that affects the therapy, response, and prognosis of patients with PCa. Due to this broad range of clinical behavior, it is required to differentiate clinically significant prostate cancers (csPCa) tumors, defined as presence of Gleason pattern >4 and/or tumor volume > 0.5 ccs, and reduce detection of indolent cancers [9], since candidates for therapy from clinically insignificant tumors that can undergo active surveillance without any harm. Traditional treatment of PCa varies from radical prostatectomy (RP) or radiotherapy (RT) to watchful waiting [10, 11]. When prostate specific antigen (PSA) tests became beneficial for PCa screening, the United States gained a huge increase in the incidence of the disease [12]. Several years ago, many PCa were detected during the pathological exam of specimens from trans-urethral prostatectomies. These patients underwent surgery for benign prostatic hyperplasia (BPH), but up to 25% were found to have malignancy [13, 14]. However, the frequency of detecting such incidental cancers has gone down since PSA came into existence, as most of the men undergoing surgery for BPH have their PSA tested.

PCa is generally diagnosed with non-targeted systematic trans-rectal ultrasound (TRUS)-guided biopsy in patients with elevated PSA or abnormal digital rectal examination (DRE).

2. Prostate cancer diagnosis

2.1. Prostate specific antigen (PSA)

PSA is a natural enzyme that is produced entirely by the prostatic epithelial cells and is used as a marker for PCa. However, PSA is not cancer-specific as BPH, prostatitis and other urinary symptoms may elevate PSA levels. There is no absolute PSA level which indicates PCa and there is no PSA level below, which a man is assured not to have PCa, although higher PSA is associated with risk of PCa [15]. Traditionally, a level ≥ 4 ng/ml has been well-known as suspicious of PCa that indicated the need for biopsies. However, at this level, only about 30% of men with elevated levels will have PCA and normal levels may falsely exclude the presence of PCa, suggesting that PSA should not be used to exclude or diagnose PCa [16–20].

2.2. Digital rectal exam (DRE)

DRE is an essential part of the clinical exam of the patient when a tumor is palpable. Over 70% of lesions are located in the peripheral zone (PZ) and are palpable when they are bigger than a certain size [21]. Twenty-five percent of the tumors are located in the transitional zone (TZ) and cannot be reachable by DRE because of their location. Other than that as PCa is now

detected at smaller tumor volumes and earlier stages, the number of palpable tumors is significantly reduced. This decreases sensitivity and specificity of the DRE [22–25]. Suspicious outcomes at DRE are an indicator of more aggressive PCa [26, 27] and trigger the need for prostate biopsies [27].

2.3. TRUS and TRUS guided biopsy (TRUSgBX)

TRUS is the typical imaging modality for assessing the prostate. Histological examination of 10–12 TRUSgBX cores from standard zones in the prostate is a gold standard for diagnosis of PCa [28]. Prostate biopsies have played a role from pure cancer detection to clinical management in the past several years. TRUS is typically the best way for measuring the volume of the prostate gland as well as guiding the biopsy needle; however, it lacks in both specificity and sensitivity for detection of PCa [28, 29]. Most of the lesions appear hypoechoic compared to the normal PZ; but some lesions are barely visible since about half of the cancer lesions are iso-echoic [29, 30] and cannot be detected. In addition, evaluation of the TZ on TRUS is limited because of the heterogeneity in the appearance caused by BPH making it difficult to detect especially the tumors located anteriorly. Thus, there is a considerable risk that a tumor is either being missed or the aggressive part of the tumor is not picked by the systematic biopsies. This may result in either repeated biopsies or incorrect Gleason score (GS).

TRUS guided prostate biopsy samples only a small part of the gland with a high possibility that the biopsy results may not catch the most aggressive tumor in the gland accurately [31, 32]. Non-targeted TRUSgBX usually takes 6–12 core biopsies of the PZ, which harbors about 70% of PCa [33]. The limitations of non-targeted TRUSgBX are well discussed in the recent year studies [34] with over 20% of false negative rate [35–37]. Also, non-targeted TRUSgBX may not provide accurate information about the volume and aggressiveness of PCa. It's been reported in some recent studies that after RP, 30–45% of the patients are upstaged from their initial diagnosis at TRUSgBX [38]. The anterior gland, TZ, and apex of the gland, which are recognized as areas with high possibilities of containing csPCa, are known to be under/not-sampled at standard TRUSgBX [39]. Since treatment protocol is completely based on risk stratification and depend on accurate GS, these limitations are very critical. It also leads to over-diagnosis of indolent PCa, which provides no benefit to the patients, and under-diagnoses of clinically significant tumors, which potentially harms patients. It has been reported that approximately 60% of patients with a diagnosis of indolent tumor choose aggressive treatment options such as RP, leading to numerous complications [40, 41]. The biopsies can also result in complications including bleeding and infections [42, 43]. Endoscopic ultrasound-guided fine needle aspiration (EUS-FNA) biopsy requires sedation and is associated with significant risks of complications such as pancreatitis, bowel perforation, and aspiration, which can be fatal [44]. In addition, confounding issue with needle biopsy is that most of the tumor mass is made up of stromal cells, not the epithelial cancer cells. Despite being the gold standard, EUS-FNA only has a sensitivity of 75–94% and a specificity of 78–95% [45]. The current diagnostic paradigm for PCa diagnosis has low diagnostic accuracy when they are associated with significant risk and cost [46].

3. Gleason scores (GS) for grading PCa

The histopathological aggressiveness of PCa is graded by the GS [47, 48]. The cancer tissue is graded on a scale from 1 to 5 based on the appearance of the cancerous cells and histopathological arrangement. This discrepancy between cancer and normal tissue reflects the aggressiveness of cancer. Since more than one class of Gleason grade is usually present in the biopsy tissue, a combination GS (ranging from 2 to 10) combining the dominant and the highest grade is assigned. The GS is intensely correlated to the clinical characteristics of the tumor and is a potent prognostic factor for treatment response. High GS indicates increased tumor aggressiveness and increased risk of tumor spread with a worse prognosis [49–52]. Hence, it has been suggested to divide the GS into risk groups based on the risk of metastasis and progression [53]. The risk assessment of a patient with diagnosed PCa and the treatment plan is highly based on the GS from TRUSgBX, which can be inaccurate because of sampling error, considering that the GS is upgraded in about 30% of the patient after RP [54]. Incorrect biopsy reported GS can result in incorrect risk stratification and possible under or over-treatment. The change of the reported GS during the past years with broadening of the Gleason grade 4 criteria [55] to improve the correlation between biopsy and RP GSs has resulted in a significant upgrade of tumor GS and made it difficult to compare pathological data over time. GS, as one of the best indicators of PCa, is a strong determinant of treatment selection. RP GS is an established prognostic indicator for recurrence of the disease. Therefore, accurate prediction of the final RP GS is critical. Clinical staging of PCa is based on the TNM classification [55, 56].

4. Magnetic resonance imaging (MRI) of the prostate

MRI of the prostate is performed on 1.5–3.0 Tesla MRI scanners combined with a pelvic phased-array coil placed over the pelvis with or without an endorectal coil (ERC) depending on the clinical situation. ERC, which is placed in the rectum just posterior to the prostate gland, reduces motion artifacts, and enhances image quality; but it has some disadvantages including increased scan time, increased costs, and reduced patient compliance because of the location of the coil in the rectum. The majority of prostatic MRI examinations can be performed with acceptable image quality without an ERC because of the increased spatial resolution (the ability to separate two dense structures from each other) and the increased signal-to-noise ratio on 3.0 T MRI. However, several studies reported improved image quality and diagnostic performance with an ERC [57, 58]. The European society of urogenital radiology's (ESUR) MR prostate guidelines states that the use of an ERC is optional for detection and preferable for staging at 3.0 T MRI [59].

4.1. Multi-parametric MRI (mpMRI)

Multi-parametric (MP) MRI, as the most specific and sensitive imaging modality in PCa management, has been reported to be the reference standard for prostate imaging endorsed [60, 61]. While TRUSgBX evaluates a limited piece of the prostate gland, magnetic resonance (MR)

images provide detailed information about the whole prostate gland and potentially may be more accurate than random TRUSgBX [62]. The development of mp-MRI provides new possibilities in detection, characterization of the lesson and staging of PCa due to its high resolution and soft-tissue contrast [62]. Recently published data [62–67] indicates the rapidly growing use of mpMRI as the most specific and sensitive diagnostic imaging modality for PCa management. MpMRI provides detailed information about the morphological, metabolic, and cellular changes in the prostate as well as characterize tissue vascularity and correlate it to tumor aggressiveness [68, 69]. MP MRI sequences include high-resolution anatomical T2-weighted (T2W) and T1-weighted (T1W) images in combination with one or more functional MRI techniques such as diffusion-weighted imaging (DWI) and dynamic contrast-enhanced (DCE) imaging [63]. Two recently reported meta-analyses revealed that mpMRI has a high negative predictive value (NPV) for the detection of csPCa [70, 71], and it has been shown that mpMRI can estimate grade of PCa compared to histopathology results with a high degree of accuracy [72, 73]. Being noninvasive, a pathway with mpMRI as a predicting test in order to determine, which men with an elevated PSA undergo biopsy might reduce unnecessary biopsies, which are the pitfalls of routine screening practice and improve detection and diagnostic accuracy.

4.2. Multi-parametric MRI (mpMRI) pitfalls

There are several interpretive pitfalls, which have been reported [74] to be encountered at mpMRI of the prostate: Normal anatomic structures can mimic anterior and TZ located lesions; post-biopsy hemorrhage can mimic PZ PCa on T2W MRI; BPH resembles TZ PCa; acute and chronic prostatitis mimics PCa; ductal variant adenocarcinoma may be occult on T2W MRI. Moreover, technical pitfalls may be encountered at MP-MRI of the prostate: T2W motion correction with radial acquisition obscures some PCa; visual/quantitative analysis of DWI for tumor detection/grading is complex; DCE lacks standardization and is limited in the TZ; targeted biopsy of MR-detected lesions using TRUS-guidance is challenging. A failure to recognize and correct these types of errors may result in suboptimal care. False positive diagnoses of areas of potential cancers at mpMRI generate clinical uncertainty and often lead to multiple pointless biopsies or in certain cases surgical management of low-grade disease. Failure to recognize clinically significant cancers in males could result in suboptimal patient outcomes [74].

4.3. Accuracy of mpMRI

A study by Borofsky et al. [75] showed that of the 162 lesions, 136 (84%) were correctly identified with mpMRI and 16% were missed. In their study, among the lesions missed at mpMRI, GS was 3 + 4 in 17 (65%), 4 + 3 in one (4%), 4 + 4 in seven (27%), and 4 + 5 in one (4%). They reported that mpMRI has excellent sensitivity in the detection of PCa on an overall patient basis; however, a substantial number of cancers are missed either because lesions are not apparent or because they are too subtle for detection. Of those missed lesions, 58% were not visualized or were characterized as benign findings even at the second-look evaluation. They conclude that clinically important lesions can be missed, or their size can be underestimated

at mpMRI [75]. Some previous studies also showed that in some cases tumors were invisible including lesions with pathologic GS greater than 3 + 4 and pathologic volume of more than 0.5 mL [75, 76]. The subset of missed lesions that could not be seen despite focused search on second look suggests that truly invisible lesions do exist.

A recent meta-analysis of seven studies including 526 patients showed a pooled sensitivity of 74% for mpMRI in the detection of clinically important cancers [77]. When compared with the current paradigm of PSA measurement and TRUSgBX, the introduction of mpMRI is clearly an improvement. It has recently been demonstrated in a prior cohort study by Ahmed et al. [78], that using mpMRI, allows 27% of patients to avoid a primary biopsy and diagnosis of 5% fewer clinically non-csPCa; and if subsequent TRUSgBX were directed by mpMRI findings, more cases of csPCa might be detected compare to the standard pathway of TRUSgBX for all [78]. This approach could potentially save a quarter of the population from the cost and complications of TRUSgBX. Rosenkrantz et al. [79] showed that mpMRI had a sensitivity of 76% when compared with matched pathology specimens. Similar studies by Le et al. [80] and Russo et al. [81] using pathology results as the reference standard showed 80–90% sensitivity. However, they found that 30% of tumors with a GS > 7 and larger than 1.0 cm were missed at MR imaging [80]. De Visschere et al. [82] reported that the majority of missed lesions were low grade and confined to the organ. A retrospective review of mpMRI in patients with missed lesions in their study revealed that the majority of missed lesions had a lower score, and PCa was multifocal in these patients. A paired analysis in patients in whom prospective reading missed lesions revealed that missed lesions were two to three times smaller in volume (0.86 mL vs. 2.13 mL, P = 0.001), which can be possibly explained by limitations associated with spatial resolution of MR imaging. [75, 82]

5. Conclusion

In conclusion, mpMRI has become an important factor for patients being enrolled in active surveillance protocols for the management of low-grade PCa. mpMRI is a proven imaging modality that can accurately detect csPCa. Several pitfalls, both interpretive and technical, may be encountered at mpMRI of the prostate, and a failure to recognize these pitfalls can lead to suboptimal patient care. Targeted biopsies of mpMRI detected lesions pose a challenge in clinical practice. The limitations of TRUSgBX should be acknowledged in order to improve the diagnostic accuracy of targeted biopsies and finally a detailed understanding of these mpMRI pitfalls is critical for the MR practitioner involved in the management of PCa.

Author details

Alireza Ziaei

Address all correspondence to: aziaei@bwh.harvard.edu

Harvard Medical School, Brigham and Women's Hospital, Boston, USA

References

[1] American Cancer Society. Cancer Facts & Figures 2016. Atlanta: American Cancer Society; 2016

[2] Boesen L. Multiparametric MRI in detection and staging of prostate cancer. Danish Medical Bulletin (online). 2017;**64**(2)

[3] Jemal A, Siegel R, Ward E, Murray T, Xu J, Smigal C, Thun MJ. Cancer statistics, 2006. CA: a Cancer Journal for Clinicians. 2006;**56**(2):106-130

[4] Deongchamps BN, Singh A, Haas GP. Epidemiology of prostate cancer in African: Another step in the understanding of the disease? Current Problems in Cancer. 2007;**31**(3):226-236

[5] Sakr WA, Haas GP, Cassin BF, Pontes JE, Crissman JD. The frequency of carcinoma and intraepithelial neoplasia of the prostate in young male patients. The Journal of Urology. 1993;**150**(2 Pt 1):379-385

[6] Miller KD, Siegel RL, Lin CC, et al. Cancer treatment and survivorship statistics, 2016. CA: a Cancer Journal for Clinicians. 2016;**66**(4):271-289

[7] Loeb S, Bjurlin MA, Nicholson J, et al. Overdiagnosis and overtreatment of prostate cancer. European Urology. 2014;**65**(6):1046-1055

[8] Etzioni R, Penson DF, Legler JM, Di Tommaso D, Boer R, Gann PH, Feuer EJ. Overdiagnosis due to prostate-specific antigen screening: Lessons from US prostate cancer incidence trends. Journal of the National Cancer Institute. 2002 Jul 3;**94**(13):981-990

[9] Wolters T, Roobol MJ, van Leeuwen PJ, et al. A critical analysis of the tumor volume threshold for clinically insignificant prostate cancer using a data set of a randomized screening trial. The Journal of Urology. 2011;**185**(1):121-125

[10] National Comprehensive Cancer Network (NCCN). Clinical practice guidelines in oncology: prostate cancer. Fort Washington, PA; 2012. Available via http://www.nccn.com/files/cancer-guidelines/prostate/index.html#/1. [Accessed Sept. 13, 2013]

[11] Prostate Cancer Canada. Prostate cancer Canada network. Toronto, ON Canada; 2014. Available via http://prostatecancer.ca. [Accessed Sept. 2014]

[12] Potosky AL, Miller BA, Albertsen PC, Kramer BS. The role of increasing detection in the rising incidence of prostate cancer. Journal of the American Medical Association. 1995;**273**(7):548-552

[13] Armenian HK, Lilienfeld AM, Diamond EL, Bross ID. Relation between benign prostatic hyperplasia and cancer of the prostate. A prospective and retrospective study. Lancet. 1974;**2**(7873):115-117

[14] Bostwick DG, Cooner WH, Denis L, Jones GW, Scardino PT, Murphy GP. The association of benign prostatic hyperplasia and cancer of the prostate. Cancer. 1992;**70** (1 Suppl):291-301

[15] Hernández J, Thompson IM. Prostate-specific antigen: A review of the validation of the most commonly used cancer biomarker. Cancer. 2004;**101**:894-904

[16] Thompson IM, Pauler DK, Goodman PJ, Tangen CM, Lucia MS, Parnes HL, et al. Prevalence of prostate cancer among men with a prostate-specific antigen level < or = 4.0 ng per milliliter. The New England Journal of Medicine. 2004;**350**:2239-2246

[17] Catalona WJ, Hudson MA, Scardino PT, Richie JP, Ahmann FR, Flanigan RC, et al. Selection of optimal prostate specific antigen cutoffs for early detection of prostate cancer: Receiver operating characteristic curves. The Journal of Urology. 1994;**152**:2037-2042

[18] De Angelis G, Rittenhouse HG, Mikolajczyk SD, Blair Shamel L, Semjonow A. Twenty years of psa: From prostate antigen to tumor marker. Revista de Urología. 2007;**9**:113-123

[19] Djavan B, Ravery V, Zlotta A, Dobronski P, Dobrovits M, Fakhari M, et al. Prospective evaluation of prostate cancer detected on biopsies 1, 2, 3 and 4: When should we stop? The Journal of Urology. 2001;**166**:1679-1683

[20] Obort AS, Ajadi MB, Akinloye O. Prostate-specific antigen: Any successor in sight? Revista de Urología. 2013;**15**:97-107

[21] Carvalhal GF, Smith DS, Mager DE, Ramos C, Catalona WJ. Digital rectal examination for detecting prostate cancer at prostate specific antigen levels of 4 ng/ml. Or less. The Journal of Urology. 1999;**161**:835-839

[22] Varenhorst E, Berglund K, Löfman O, Pedersen K. Interobserver variation in assessment of the prostate by digital rectal examination. British Journal of Urology. 1993;**72**:173-176

[23] Chodak GW. Early detection and screening for prostatic cancer. Urology. 1989;**34**:10-12 discussion 46-56

[24] Pedersen KV, Carlsson P, Varenhorst E, Löfman O, Berglund K. Screening for carcinoma of the prostate by digital rectal examination in a randomly selected population. BMJ. 1990;**300**:1041-1044

[25] Catalona WJ, Richie JP, Ahmann FR, Hudson MA, Scardino PT, Flanigan RC, et al. Comparison of digital rectal examination and serum prostate specific antigen in the early detection of prostate cancer: Results of a multicenter clinical trial of 6,630 men. The Journal of Urology. 1994;**151**:1283-1290

[26] Gosselaar C, Roobol MJ, Roemeling S, Schröder FH. The role of the digital rectal examination in subsequent screening visits in the European randomized study of screening for prostate cancer (ERSPC), Rotterdam. European Urology. 2008;**54**:581-588

[27] Okotie OT, Roehl KA, Han M, Loeb S, Gashti SN, Catalona WJ. Characteristics of prostate cancer detected by digital rectal examination only. Urology. 2007;**70**:1117-1120

[28] Heidenreich A, Aus G, Bolla M, Joniau S, Matveev VB, Schmid HP, Zattoni F. EAU guidelines on prostate cancer. Actas urologicas espanolas. Feb 2009;**33**(2):113-126

[29] Harvey CJ, Pilcher J, Richenberg J, Patel U, Frauscher F. Applications of transrectal ultrasound in prostate cancer. The British Journal of Radiology. 2012;**85**(Spec Iss 1):S3-S17

[30] Spajic B, Eupic H, Tomas D, Stimac G, Kruslin B, Kraus O. The incidence of hyperechoic prostate cancer in transrectal ultrasound-guided biopsy specimens. Urology. 2007; **70**:734-737

[31] Quon JS, Moosavi B, Khanna M, Flood TA, Lim CS, Schieda N. False positive and false negative diagnoses of prostate cancer at multi-parametric prostate MRI in active surveillance. Insights into imaging. 2015 Aug 1;**6**(4):449-463

[32] Epstein JI, Feng Z, Trock BJ, Pierorazio PM. Upgrading and downgrading of prostate cancer from biopsy to radical prostatectomy: Incidence and predictive factors using the modified Gleason grading system and factoring in tertiary grades. European Urology. 2012 May 31;**61**(5):1019-1024

[33] Rothwax JT, George AK, Wood BJ, Pinto PA. Multiparametric MRI in biopsy guidance for prostate cancer: Fusion-guided. BioMed Research International. 2014;**2014**:439171. DOI: 10.1155/2014/439171

[34] Schoots IG, Roobol MJ, Nieboer D, Bangma CH, Steyerberg EW, Hunink MM. Magnetic resonance imaging–targeted biopsy may enhance the diagnostic accuracy of significant prostate cancer detection compared to standard transrectal ultrasound-guided biopsy: A systematic review and meta-analysis. European Urology. 2015 Sep 30;**68**(3):438-450

[35] Eskew LA, Bare RL, McCullough DL. Systematic 5 region prostate biopsy is superior to sextant method for diagnosing carcinoma of the prostate. The Journal of Urology. 1997;**157**:199-202. DOI: 10.1016/S0022-5347(01)65322-9

[36] Presti JC Jr, O'Dowd GJ, Miller MC, Mattu R, Veltri RW. Extended peripheral zone biopsy schemes increase cancer detection rates and minimize variance in prostate specific antigen and age related cancer rates: Results of a community multi-practice study. The Journal of Urology. 2003;**169**:125-129. DOI: 10.1016/S0022-5347(05)64051-7

[37] Babaian RJ, Toi A, Kamoi K, et al. A comparative analysis of sextant and an extended 11-core multisite directed biopsy strategy. The Journal of Urology. 2000;**163**:152-157. DOI: 10.1016/S0022-5347(05)67993-1

[38] Noguchi M, Stamey TA, McNeal JE, Yemoto CM. Relationship between systematic biopsies and histological features of 222 radical prostatectomy specimens: Lack of prediction of tumor significance for men with nonpalpable prostate cancer. The Journal of Urology. 2001;**166**:104-109. DOI: 10.1016/S0022-5347(05)66086-7

[39] Bott SR, Young MP, Kellett MJ, Parkinson MC. Anterior prostate cancer: Is it more difficult to diagnose? BJU International. 2002;**89**:886-889

[40] Cooperberg MR, Broering JM, Carroll PR. Time trends and local variation in primary treatment of localized prostate cancer. Journal of Clinical Oncology. 2010;**28**(7):1117-1123

[41] Mols F, Korfage IJ, Vingerhoets AJ, Kil PJ, Coebergh JW, Essink-Bot ML, Van de Poll-Franse LV. Bowel, urinary, and sexual problems among long-term prostate cancer survivors: A population-based study. International Journal of Radiation Oncology, Biology, and Physics. 2009 Jan 1;**73**(1):30-38

[42] Adibi M, Pearle MS, Lotan Y. Cost-effectiveness of standard vs intensive antibiotic regimens for transrectal ultrasonography (TRUS)-guided prostate biopsy prophylaxis. BJU International. 2012;**110**(2 Pt 2)

[43] Taylor AK, Zembower TR, Nadler RB, Scheetz MH, Cashy JP, Bowen D, Murphy AB, Dielubanza E, Schaeffer AJ. Targeted antimicrobial prophylaxis using rectal swab cultures in men undergoing transrectal ultrasound guided prostate biopsy is associated with reduced incidence of postoperative infectious complications and cost of care. The Journal of Urology. 2012 Apr 30;**187**(4):1275-1279

[44] Merchea A, Cullinane DC, Sawyer MD, et al. Esophagogastroduodenoscopy-associated gastrointestinal perforations: A single-center experience. Surgery. 2010;**148**(4):876-880 discussion 881-872

[45] Bournet B, Selves J, Grand D, et al. Endoscopic ultrasound-guided fine-needle aspiration biopsy coupled with a KRAS mutation assay using allelic discrimination improves the diagnosis of pancreatic cancer. Journal of Clinical Gastroenterology. 2015;**49**(1):50-56

[46] Court CM, Ankeny JS, Hou S, Tseng HR, Tomlinson JS. Improving pancreatic cancer diagnosis using circulating tumor cells: Prospects for staging and single-cell analysis. Expert Review of Molecular Diagnostics. Nov 2, 2015;**15**(11):1491-1504

[47] Epstein JI, Allsbrook WC, Amin MB, Egevad LL. The 2005 International Society of Urological Pathology (ISUP) consensus conference on Gleason grading of prostatic carcinoma. The American Journal of Surgical Pathology. 2005;**29**:1228-1242

[48] Gleason DF, Mellinger GT. Prediction of prognosis for prostatic adenocarcinoma by combined histological grading and clinical staging. The Journal of Urology. 1974;**111**:58-64

[49] Epstein JI, Allsbrook WC, Amin MB, Egevad LL. Update on the Gleason grading system for prostate cancer. Urologic Pathologists. 2006;**13**:57-59

[50] Egevad L, Granfors T, Karlberg L, Bergh A, Stattin P. Prognostic value of the Gleason score in prostate cancer. BJU International. 2002;**89**:538-542

[51] Rusthoven CG, Carlson JA, Waxweiler TV, Yeh N, Raben D, Flaig TW, et al. The prognostic significance of Gleason scores in metastatic prostate cancer. Urologic Oncology. 2014;**32**:707-713

[52] Brimo F, Montironi R, Egevad L, Erbersdobler A, Lin DW, Nelson JB, et al. Contemporary grading for prostate cancer: Implications for patient care. European Urology. 2013;**63**:892-901

[53] Pierorazio PM, Walsh PC, Partin AW, Epstein JI. Prognostic Gleason grade grouping: Data based on the modified Gleason scoring system. BJU International. 2013;**111**:753-760

[54] Epstein JI, Feng Z, Trock BJ, Pierorazio PM. Upgrading and downgrading of prostate cancer from biopsy to radical prostatectomy: Incidence and predictive factors using the modified Gleason grading system and factoring in tertiary grades. European Urology. 2012;**61**:1019-1024

[55] Delahunt B, Miller RJ, Srigley JR, Evans AJ, Samaratunga H. Gleason grading: Past, present and future. Histopathology. 2012;**60**:75-86

[56] Sobin L, Gospodarowicz MWC. TNM Classification of Malignant Tumours. Urological Tumours. International Union against Cancer. 7th ed. Wiley-Blackwell: Hoboken, NJ; 2009

[57] Sciarra A, Barentsz J, Bjartell A, Eastham J, Hricak H, Panebianco V, et al. Advances in magnetic resonance imaging: How they are changing the management of prostate cancer. European Urology. 2011;**59**:962-977

[58] Steyn JH, Smith FW. Nuclear magnetic resonance imaging of the prostate. British Journal of Urology. 1982;**54**:726-728

[59] Borre M, Lundorf E, Marcussen N, Langkilde NC, Wolf H. Phased array magnetic resonance imaging for staging clinically localised prostate cancer. Acta Oncologica. 2005;**44**:589-592

[60] Eberhardt SC, Carter S, Casalino DD, et al. ACR appropriateness criteria prostate cacer–pretreatment detection, staging, and surveillance. Journal of the American College of Radiology. 2013;**10**:83-92

[61] Barentsz JO, Richenberg J, Clements R, et al. ESUR prostate MR guidelines 2012. European Radiology. 2012;**22**:746-757

[62] Quon JS, Moosavi B, Khanna M, Flood TA, Lim CS, Schieda N. False positive and false negative diagnoses of prostate cancer at multi-parametric prostate MRI in active surveillance. Insights into imaging. 2015 Aug 1;**6**(4):449-463

[63] Boesen L. Multiparametric MRI in detection and staging of prostate cancer. Scandinavian Journal of Urology. 2015;**49**:25-34

[64] Chabanova E, Balslev I, Logager V, Hansen A, Jakobsen H, Kromann-Andersen B, et al. Prostate cancer: 1.5 T endo-coil dynamic contrast-enhanced MRI and MR spectroscopy--correlation with prostate biopsy and prostatectomy histopathological data. European Journal of Radiology. 2011;**80**:292-296

[65] Barentsz JO, Richenberg J, Clements R, Choyke P, Verma S, Villeirs G, et al. ESUR prostate MR guidelines 2012. European Radiology. 2012;**22**:746-757

[66] Heijmink SWTPJ, Fütterer JJ, Hambrock T, Takahashi S, Scheenen TWJ, Huisman HJ, et al. Prostate cancer: Bodyarray versus endorectal coil MR imaging at 3 T--comparison of image quality, localization, and staging performance. Radiology. 2007;**244**:184-195

[67] Turkbey B, Merino MJ, Gallardo EC, Shah V, Aras O, Bernardo M, et al. Comparison of endorectal coil and nonendorectal coil T2W and diffusion-weighted MRI at 3 tesla for localizing prostate cancer: Correlation with wholemount histopathology. Journal of Magnetic Resonance Imaging. 2014;**39**:1443-1448

[68] Heijmink SWTPJ, Fütterer JJ, Strum SS, Oyen WJG, Frauscher F, Witjes JA, et al. State-of-the-art uroradiologic imaging in the diagnosis of prostate cancer. Acta Oncologica. 2011;**50**(Suppl 1):25-38

[69] Boesen L, Thomsen HS. Magnetic resonance imaging in management of prostate cancer. Ugeskrift for Laeger. 2013;**175**:1630-1633

[70] Hamoen EH, de Rooij M, Witjes JA, Barentsz JO, Rovers MM. Use of the prostate imaging reporting and data system (PI-RADS) for prostate cancer detection with multiparametric magnetic resonance imaging: A diagnostic meta-analysis. European Urology. 2014;**67**:1112-1121. DOI: 10.1016/j.eururo.2014.10.033

[71] de Rooij M, Hamoen EH, Futterer JJ, Barentsz JO, Rovers MM. Accuracy of multiparametric MRI for prostate cancer detection: A meta-analysis. American Journal of Roentgenology. 2014;**202**:343-351. DOI: 10.2214/AJR.13.11046

[72] Hegde JV, Mulkern RV, Panych LP, et al. Multiparametric MRI of prostate cancer: An update on state-of-the-art techniques and their performance in detecting and localizing prostate cancer. Journal of Magnetic Resonance Imaging. 2013;**37**:1035-1054

[73] Schoots IG, Petrides N, Giganti F, et al. Magnetic resonance imaging in active surveillance of prostate cancer: A systematic review. European Urology. 2015;**67**:627-636

[74] Quon JS, Moosavi B, Khanna M, Flood TA, Lim CS, Schieda N. False positive and false negative diagnoses of prostate cancer at multi-parametric prostate MRI in active surveillance. Insights into imaging. 2015 Aug 1;**6**(4):449-463

[75] Borofsky S, George AK, Gaur S, Bernardo M, Greer MD, Mertan FV, Taffel M, Moreno V, Merino MJ, Wood BJ, Pinto PA. What are we missing? False-negative cancers at multiparametric MR imaging of the prostate. Radiology. 2017 Oct;**20**:152877

[76] Vargas HA, Hötker AM, Goldman DA, Moskowitz CS, Gondo T, Matsumoto K, Ehdaie B, Woo S, Fine SW, Reuter VE, Sala E. Updated prostate imaging reporting and data system (PIRADS V2) recommendations for the detection of clinically significant prostate cancer using multiparametric MRI: Critical evaluation using whole-mount pathology as standard of reference. European Radiology. 2016 Jun 1;**26**(6):1606-1612

[77] de Rooij M, Hamoen EH, Fütterer JJ, Barentsz JO, Rovers MM. Accuracy of multiparametric MRI for prostate cancer detection: A meta-analysis. American Journal of Roentgenology. 2014;**202**(2):343-351

[78] Ahmed HU, Bosaily AE, Brown LC, Gabe R, Kaplan R, Parmar MK, Collaco-Moraes Y, Ward K, Hindley RG, Freeman A, Kirkham AP. Diagnostic accuracy of multi-parametric MRI and TRUS biopsy in prostate cancer (PROMIS): A paired validating confirmatory study. The Lancet. 2017 Mar 3;**389**(10071):815-822

[79] Rosenkrantz AB, Deng FM, Kim S, et al. Prostate cancer: multiparametric MRI for index lesion localization: a multiple-reader study. AJR. American Journal of Roentgenology. 2012;**199**(4):830-837

[80] Le JD, Tan N, Shkolyar E, et al. Multifocality and prostate cancer detection by multiparametric magnetic resonance imaging: Correlation with whole-mount histopathology. European Urology. 2015;**67**(3):569-576

[81] Russo F, Regge D, Armando E, et al. Detection of prostate cancer index lesions with multiparametric magnetic resonance imaging (mp-MRI) using whole-mount histological sections as the reference standard. BJU International. 2016;**118**(1):84-94

[82] De Visschere PJ, Naesens L, Libbrecht L, et al. What kind of prostate cancers do we miss on multiparametric magnetic resonance imaging? European Radiology. 2016;**26**(4):1098-1107

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