PROSTATE CANCER

CHAPTER 4

Imaging

Kaviani Fleshner Hosseini

Abbreviations and Acronyms

2D	= 2 Dimentional
ADC	= Apparent Diffusion Coefficient
cc	= Cubic Centimetre
CZ	= Central Zone
DCE	= Dynamic Contrast-Enhanced
DRE	= Digital Rectal Examination
DW	= Diffusion Weighted Image
EPE	= Extraprostatic Extension
mp-MRI	= Multiparametric MRI
MRS	= MR Spectroscopy
MSI	= Magnetic Source Imaging
PCa	= Prostate Cancer
PET	= Positron Emission Tomography
PSA	= Prostatic Specific Antigen
PZ	= Peripheral Zone
SVI	= Seminal Vesicle Invasion
SPECT	= Single-Photon Emission Computed Tomography
T1 , T1W	=T1 Weighted MRI
T2, T2W	=T2 Weighted MRI
TZ	= Transition Zone
TRUS	= Transrectal Ultrasound

Prostate cancer imaging is one the most intersting subjects in the whole field of urology. Though imaging has played a minor role in PCa screening, more and more urologists are looking to imaging examinations for answers to critical questions[1.] However, no consensus exists regarding the appropriate use of imaging modalities for evaluating primary prostate cancers[2].

Gray-scale transrectal ultrasound (TRUS) is the most common imaging modality for the prostate[3] . TRUS is mainly used to calculate prostate volume and to direct biopsy of PCa [3]. TRUS has a very limited role in the staging of PCa due to its low sensitivity and a tendency to understage PCa [3,4,5].

TRUS evaluation of the prostate consists of scanning the prostae in the sagittal and transverse planes and includes prostate volume calculation[3]. The CZ and PZ are inspected for hypoechoic lesions and contour abnormalities[3] . SVs and vasa deferentia are also fully examinied[3].

60%, 39% and 1% of all prostate cancers are hypoechic, isoechoic and hyperechoic respectively in the convetional transrectal ultrasound of prostate[3]. In other words, only 60% of tumors are visible with TRUS, and the remainder are not perceived due to their isoechogenicity[5]. On the other hand, only 17% to 57% of patients with hypoechoic lesions of prostate have prostate cancer[3,6]. A greater sensitivity for PCa detection has been reported with the addition of power colour Doppler and contrast agents [5,7-9].

Focal loss of the typically bright white periprostatic fat is suggestive of extraprostatic extension of prostate cancer and has high specificity in this regard [3,5] . Presence of small multiple calculi is a frequent and benign finding[3]. Prostatic cysts are also common and benign finding[3].

A summary of ultrasonographic modalities which are used for diagnosis of PCa has been shown in the figure 1.

Figure 1- Transrectal ultrasound of prostate (TRUS)

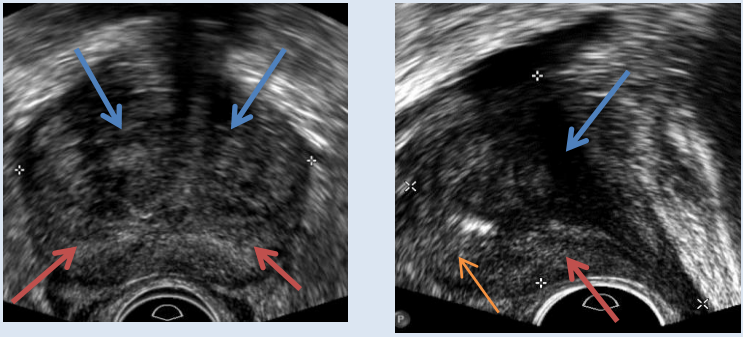


Figure 1a: Gray-scale Transrectal Ultrasound (TRUS) of prostate. Axial (left) and sagittal (right) views are used to calculate prostate volume. We also look for any hypoechoic lesions in CZ and PZ. PZ has been marked by red arrows. Blue arrows have been used to localize TZ. Orange arrow localizes the CZ.

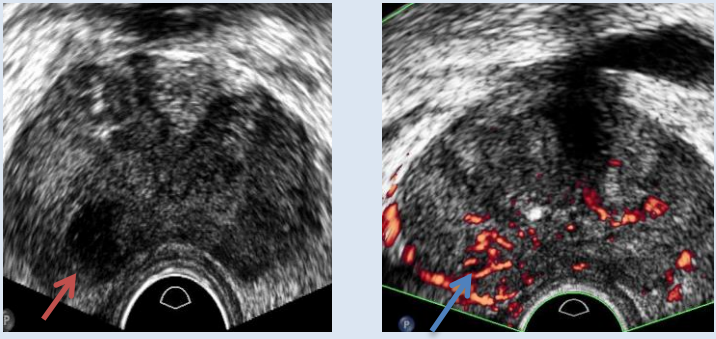


Figure 1b: Transverse gray-scale sonogram shows large hypoechoic lesion (red arrow). Power Doppler shows increased flow within and around hypoechoic lesion (blue arrow).

MRI is the most established imaging modality for localization and local staging of prostate cancer[5,10]. In comparison with DRE, TRUS and CT scan, MRI shows higher accuracy for determination of uni- or bilateral disease, extraprostatic extension (EPE) and seminal vesicle invasion (SVI), and also the invasion of adjacent structures[5].

MRI might have its greatest role in patients where there is a discrepancy between PSA and biopsy results suggesting a potential missed prostate tumor[10].

Endorectal MRI may allow for more accurate local staging[5]. Endorectal MRI improves disease detection within the gland[10, 11-17]. Also, sensitivity for detection of EPE is increased from 7% to 80% when endorectal coil is used in addition to T2W MRI relative to patients who had body coil T2W MRI [10, 18].

Endorectal MRI could help on the decision making to preserve or resect the neurovascular bundle (NVB) at the time of radical prostatectomy[5].

Multiparametric MRI (mp-MRI) is suggested for prostate cancer[19]. This includes a combination of high-resolution T2-weighted images and at least two functional MRI techniques[19].

Multiparametric MRI is highly accurate in detecting tumors >0.5 cc volume[19]. In fact, mp-MRI has sensitivity and NPV of 93% and 98% respectively in detecting high-grade cancers >0.5 cc[19].

Biopsy-related hemorrhage can mimic cancer[19]. So, MRI should be performed at least 4-6 weeks after biopsy[19].

T1W sequence is not useful for diagnosis of PCa; however, it is done before other sequences to exclude any existing hemorrhage[19].

T2-weighted MRI is the mainstay of prostate MR imaging[20]. Prostate cancers

located in PZ typically manifest as low-signal-intensity areas in the T2W images[19]. High-grade cancers tend to have lower signal intensity than low-grade cancers in this sequence[19].

Diffusion weight MRI (DW-MRI) which provides information relating to molecular movement of water also improves prostate cancer detection[10, 21-25]. Densely cellular prostate cancer has lower diffusion of water molecules than normal peripheral zone tissues. Magnetic source imaging (MSI) and apparent diffusion coefficient (ADC) are used to show suspicious foci in this method[10]. ADC values correlate with Gleason scores[19].

DW imaging improves specificity for PCa relative to T2w alone[19]. In patients with clinical suspicion of prostate cancer who have negative biopsy results, DW imaging should be included to study to decrease false positive or negative of other modalities due to possibility of TZ tumors[20].

MR-Spectroscopy (MRS) is a different MRI modality which is used to increase its sensitivity for detection of prostate cancer and shows a sensitivity of 73% in this regard[10, 26, 27.] In fact, it provides metabolic information about prostatic tissue. MRS helps to determine tumor aggressiveness with a trend toward increasing in (choline + creatine) / citrate ratio with increasing Gleason grade [10].

Dynamic contrast- enhanced MRI (DCE-MRI) is another modality to increase MRI sensitivity. It is used to evaluate tumor vascularity[19]. Prostate cancer shows early enhancement and early washout in this method[10]. Higher grades show more enhancement and quicker washout[10]. However, small low grade tumors may not show this feature appropriately[10.]

Multiparametric MRI for diagnosis and local staging of prostate cancer has been summarized in figure 2 and 3.

Figure2- Multiparametric MRI for diagnosis and local staging of prostate cancer

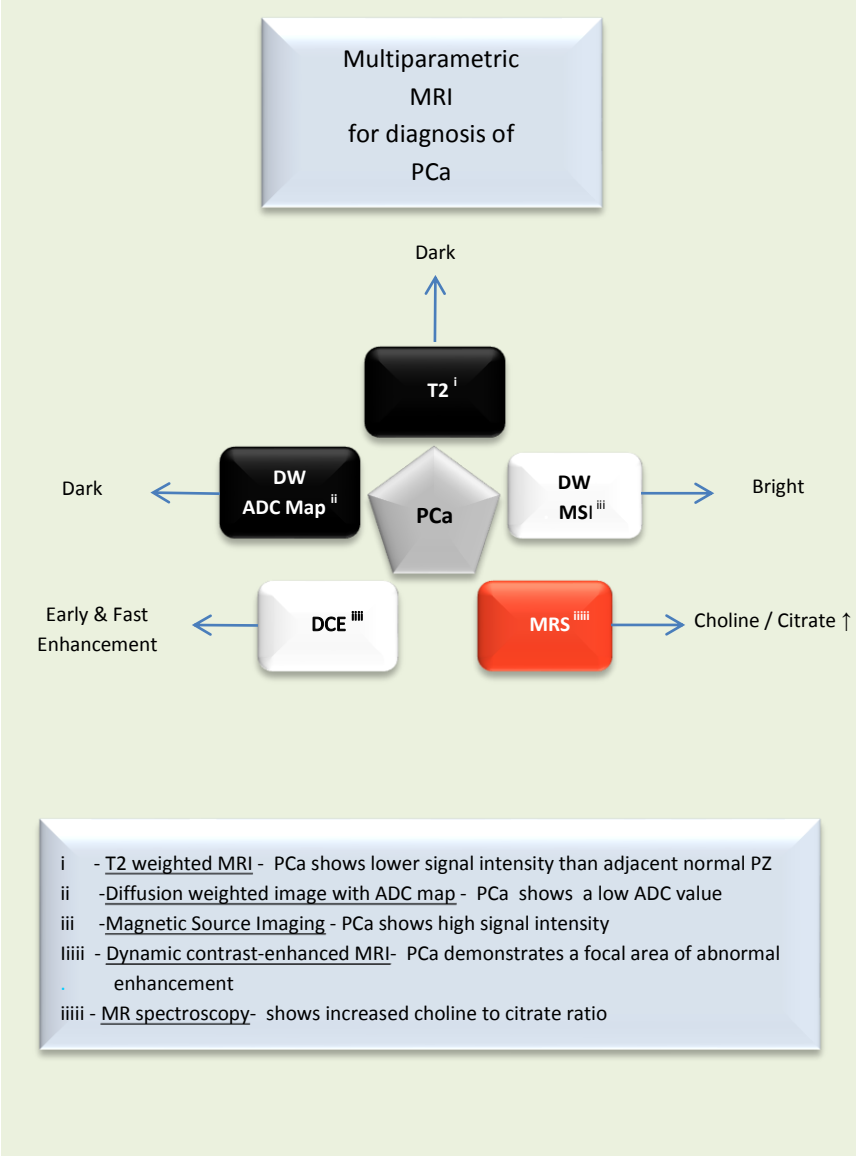
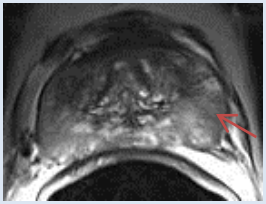


Figure 3- Multiparametric MRI for diagnosis and local staging of prostate cancer



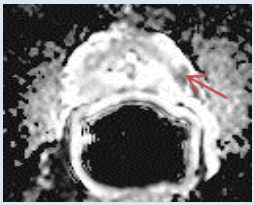
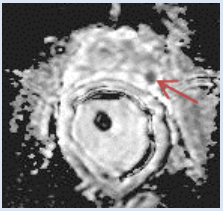
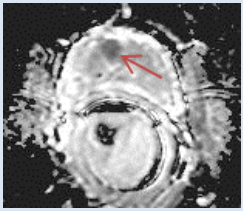


Figure 3a- Suspicious area in T2 weighted MRI (right). Prostate cancer shows lower signal intensity than adjacent normal PZ. DW- ADC Map of the same lesion which shows a low ADC value of suspicious area (right).





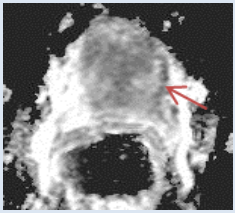
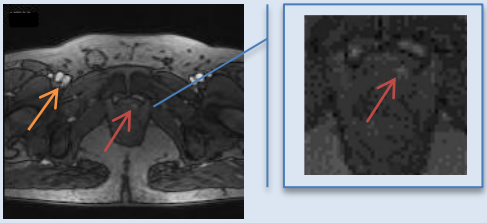


Figure 3b- Suspicious areas in Diffusion weighted image with ADC map. Prostate cancer shows a low ADC value.

Figure 3c- Suspicious area in DCE. There is early enhancement in this lesion (red arrows). Look at iliac arteries and veins which are still enhanced at this early phase (orange arrow).



As mentioned previously, MRI might have its greatest role in patients where there is a discrepancy between PSA and biopsy results suggesting a potential missed prostate tumor[10].

MRI may help in targeting biopsies[10]. Techniques using MR to guide needle insertion have been introduced but have not become widely available[28].

An interesting techinque is fusion of MRI with TRUS images. In this technique, pre-interventional MRI images and real time 2D ultrasound scans are used which provide us with a cheaper and faster solution for MRI-guided prostate biopsy procedures which nonetheless takes advantage of the ability of MR to detect prostate cancers[28].

Pelvic nodes status has important prognostic and therapeutic role in prostate cancer. Patients may be spared nodal evaluation if they have a clinical stage ≤ T2a, PSA < 20 ng/mL and Gleason score ≤ 6.

CT scan and MRI perform similarly in the evaluation of of pelvic lymph node metastases, although CT seems to be slightly better in this regard [5,29].

Therosholds of 0.8 and 1 cm for round and oval nodes are being used as the criteria for diagnosis of lymph node metastasis in both techniques [5,30].

High-resolution MRI with superparamagnetic nanoparticles has been introduced in the detection of small and otherwise occult lymph node metastases and has shown high sensitivity and specificity in this regard but still is mainly restircted to research settings [5,31-33].

Radio-immunoscintigraphy (ProstaScint) and PET scan have been investigated in order to improve the diagnosis of lymph node metastasis espeically small volume nodal disease[5,34] .Both methods are still under investigation, and further assessments are needed before they can be

recommended for routine clinical use [5,35,36].

Different imaging modalities have been used for assessment of bone metastasis from prostate cancer. Bone metastases from prostate cancer are usually blastic and appear late on the conventional X-ray[37].

Bone scan continues to be the mainstay and the initial test of choice of diagnosis for bone metastasis from prostate cancer due to its overall sensitivity and its ability to survey the entire skeleton [33].

Bone scan may not be indicated if the patient is asymptomatic , has a PSA level lower than 20 ng/mL and does not have a Gleason score higher than 8.

SPECT is more sensitive than conventional planar bone scan[33] . SPECT/CT adds anatomic details to SPECT alone[33] .

PET/CT and whole body MRI are optional tests for assessment of bone metastasis from prostate cancer and can be used in equivocal cases[5].

MR is both sensitive and specific in the diagnosis of bone metastases[33]. In fact, small volume deposits and metastases without cortical involvement may be seen earlier on MR images than on bone scans[33].

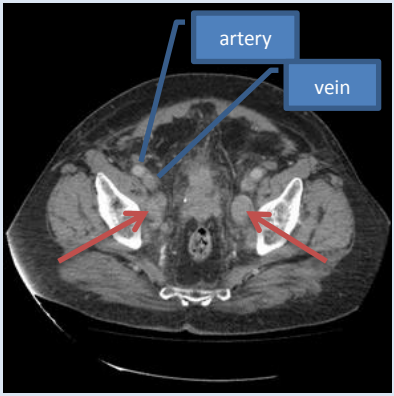
^{18}FDG PET is less sensitive than bone scan in the identification of blastic bone metastases[37]. However, ^{18}FDG PET may become positive sooner than bone scan in patients who have lesions within bone marrow[37].

On the other hand, ^{18}F-fluoride PET is likely to be more sensitive than conventional bone scan for detecting both blastic and lytic bone metastases[33].

Some of imaging modalities for evaluation of lymph nodes and bone metastasis in prostate cancer have been shown in figure 4 and 5.

Figure 4-Axial and coronal CT scan for diagnosis of lymphadenopathy in advanced PCa

Figure 5a- Axial CT scan of a patient with advanced prostate cancer with bilateral obturator lymphadenopathies (arrows). External iliac lymph nodes are divided into 3 groups. Lateral chain is located laterally along the external iliac artery. Middle chain is located between artery and vein. Medial chain which also called obturator lymph nodes is located medial and posterior to the external iliac vein.



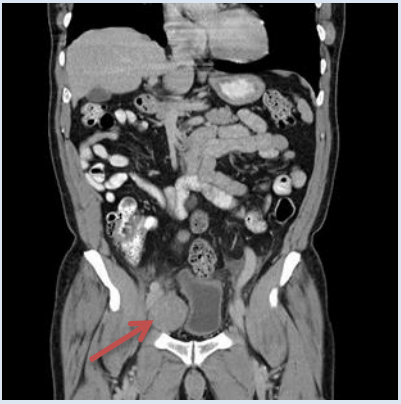


Figure 5b-Coroanl CT scan of a patient with advanced prostate cancer with external iliac lymphadenopathy (arrow).

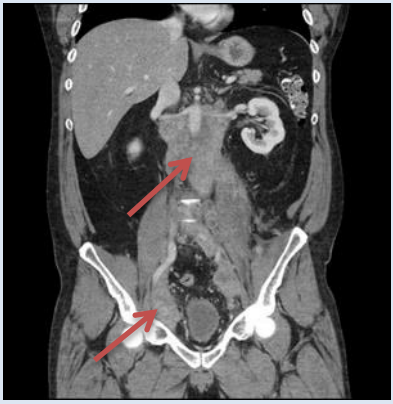


Figure 5c- Coronal CT scan of a patient with advanced prostate cancer with external iliac as well as extensive retroperitoneal lymphadenopathy (arrows).

Figure 5-Commonly used Imaging modalities for evaluating bone metastases from PCa

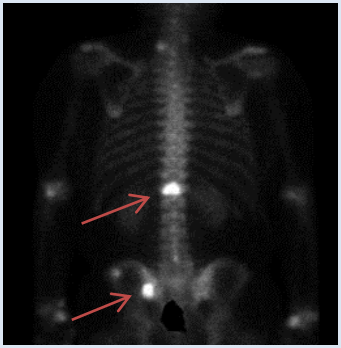


Figure 6a- Bone scan of a patient with multiple bone metastases. Two typical lesions with intense uptake have been selected (arrows).

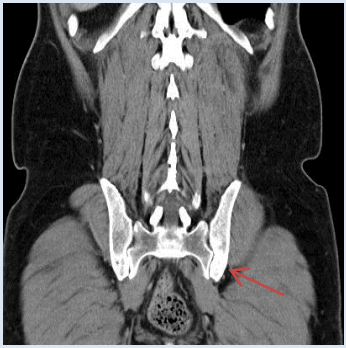
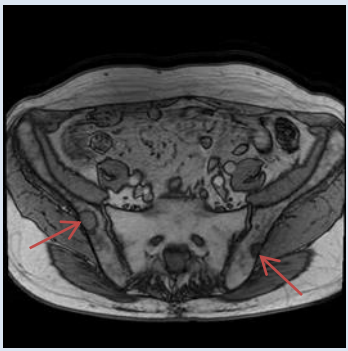


Figure 6b- Coronal CT scan of patent with blastic bone metastasis (arrow).



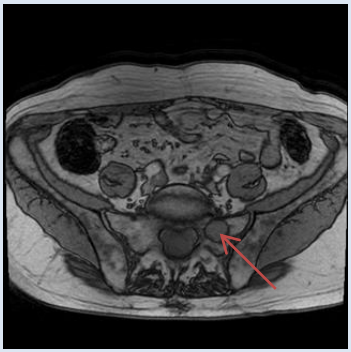


Figure 6c: T1 phase MRI of a patient with multiple bone metastases (arrows)

References

1. Bronson JG. Imaging Prostate Cancer: Before, During, and After Treatment. Imaging Economics; 2001. http://www.imagingeconomics.com/contact.asp. Accessed 5 Feb 2012.
2. Hricak H, Choyke PL, Eberhardt SC, Leibel SA, Scardino PT. Imaging Prostate Cancer: A Multidisciplinary Perspective. Radiology. 2007 Apr;243(1):28-53.
3. Gomella LG, Halpern EJ, Trabulsi EJ. Ultrasonography and Biopsy of the Prostate.In: Wein AJ, Kavousi LR, Novick AC, Partin AW, Peters CA, eds. Campbell-Walsh Urology. Vol 3. 10 ed. Philadelphia, PA Saunders; 2011.2735-2747.
4. Onur R, Littrup PJ, Pontes JE, et al. Contemporary impact of transrectal ultrasound lesions for prostate cancer detection. J Urol. 2004; 172(2):512-514.
5. Heidenreich A, Bastian PJ, Bellmunt J, et al.Guidelines on prostate cancer.Arnhem, The Netherlands: European Association of Urology;2012. http://www.uroweb.org/gls/pdf/08%20Prostate%20Cancer_LR%20March%2013th%202012.pdf.Accessed 25 Feb 2012.
6. Frauscher F, Klauser A, Halpern EJ, et al. Advances in ultrasound for the detection of prostate cancer. Ultrasound Q. 2002; 18(2):135-142.
7. Sauvain JL, Palascak P, Bourscheid D, et al. Value of power Doppler and 3D vascular sonography as a method for diagnosis and staging ofprostate cancer. Eur Urol. 2003 Jul;44(1):21-30.
8. Zalesky M, Urban M, Smerhovský Z, et al. Value of power Doppler sonography with 3D reconstruction in preoperative diagnostics of extraprostatic tumor extension in clinically localized prostate cancer. Int JUrol. 2008;15(1):68-75.
9. Smeenge M, Mischi M, Laguna Pes MP, et al. Novel contrast-enhanced ultrasound imaging in prostate cancer.World J Urol. 2011 Oct;29(5):581-7.
10. Raz O, Haider M, Trachtenberg J, Leibovici D, Lawrentschuk N. MRI for men undergoing active surveillance or with rising PSA and negative biopsies. Nat Rev Urol. 2010 Oct;7(10):543-51.
11. Kirkham AP, emberton M ,Allen C. How good is MRI at detecting and

characterising cancer within the prostate? Eur Urol. 2006 Dec; 50(6):1163-74.

12. Casciani E, Polettini E, Bertini L, et al. Prostate cancer. evaluation with endorectal MR imaging and three‐dimensional proton MR spectroscopic imaging. Radiol Med. 2004 Nov-Dec;108(5-6):530-41.
13. Fütterer JJ, Engelbrecht MR, Huisman HJ, et al. Prostate cancer: local staging at 3‐T endorectal MR imaging—early experience. Radiology. 2006 Jan;238(1):184-91.
14. Miao H, Fukatsu H, Ishigaki T. Prostate cancer detection with 3-T MRI: comparison of diffusion-weighted and T2-weighted imaging. Eur J Radiol. 2007; 61:297 –302.
15. Girouin N, Mège-Lechevallier F, Tonina Senes A, et al. Prostate dynamic contrastenhanced MRI with simple visual diagnostic criteria: is it reasonable? Eur Radiol. 2007 Jun;17(6):1498-509.
16. Hara N, Okuizumi M, Koik H , Kawaguchi M ,Bilim V. Dynamic contrast‐enhanced magnetic resonance imaging (DCe‐MRI) is a useful modality for the precise detection and staging of early prostate cancer. Prostate. 2005 Feb 1;62(2):140-7.
17. Ito H, Kamoi K, Yokoyam K, Yamada K , Nishimura T. visualization of prostate cancer using dynamic contrast‐enhanced MRI:comparison with transrectal power Doppler ultrasound. Br J Radiol. 2003 Sep;76(909):617-24.
18. Heijmink SW, Fütterer JJ, Hambrock T, et al. Prostate cancer: body‐array versus endorectal coil MR imaging at 3 T—comparison of image quality, localization, and staging performance. Radiology. 2007 Jul;244(1):184-95
19. Barentsz JO, Richenberg J, Clements R, et al. ESUR prostate MR guidelines 2012. Eur Radiol. 2012 Apr;22(4):746-57.
20. Hoeks CM, Barentsz JO, Hambrock T, et al .Prostate cancer: multiparametric MR imaging for detection, localization, and staging. Radiology. 2011 Oct;261(1):46-66.
21. Kozlowski P , Chang SD. Jones EC, et al. Combined diffusion‐weighted and dynamic contrast‐enhanced MRI for prostate cancer diagnosis‐correlation with biopsy and histopathology. J Magn Reson Imaging. 2006 Jul;24(1):108-13.
22. Issa, B. In vivo measurement of the apparent diffusion coefficient in normal

and malignant prostatic tissues using echo‐planar imaging. J Magn Reson Imaging. 2002 Aug;16(2):196-200.

23. Hosseinzadeh K, Schwarz SD. Endorectal diffusion-weighted imaging in prostate cancer to differentiate malignant and benign peripheral zone tissue. J Magn Reson Imaging. 2004 Oct;20(4):654-61.
24. Mazaheri Y , Hricak H, Fine SW ,et al. Prostate tumor volume measurement with combined T2‐weighted imaging and diffusion‐weighted MR: correlation with pathologic tumor volume. Radiology. 2009 Aug;252(2):449-57.
25. Margel D, Yap SA, Lawrentschuk N, et al. Impact of multiparametric endorectal coil prostate magnetic resonance imaging on disease reclassification among active surveillance candidates: a prospective cohort study. J Urol. 2012 Apr;187(4):1247-52.
26. Scheidler J, Hricak H, Vigneron DB, et al. Prostate cancer: localization with three‐dimensional proton MR spectroscopic imaging‐‐clinicopathologic study Radiology. 1999 Nov;213(2):473-80.
27. Wang L, Hricak H, Kattan MW, et al. Prediction of organ‐confined prostate cancer: incremental value of MR imaging and MR spectroscopic imaging to staging nomograms. Radiology. 2006 Feb;238(2):597-603.
28. Xu S, Kruecker J, Turkbey B,et al. Real-time MRI-TRUS fusion for guidance of targeted prostate biopsies. Comput Aided Surg. 2008 Sep;13(5):255-64.
29. Hoivels AM, Heesakkers RAM, Adang EM, et al. The diagnostic accuracy of CT and MRI in the staging of pelvic lymph nodes in patients with prostate cancer: a meta-analysis. Clinical Radiology. 2008;63:387-95.
30. Jager GJ, Barentsz JO, Oosterhof GO, et al. Pelvic adenopathy in prostatic and urinary bladdercarcinoma: MR-imaging with a three-dimensional T1-weighted magnetization -prepared-rapid gradient-echo sequence. Am JRoentgenol .1996 Dec;167(6):1503-7.
31. Harisinghani MG, Barentsz J, Hahn PF, et al. Noninvasive detection of clinically occult lymph-node metastases in prostate cancer. N Engl J Med. 2003 Jun; 348(25) :2491-9.
32. Heesakkers RA, Fütterer JJ, Hövels AM, et al. Prostate cancer evaluated with ferumoxtran-10enhanced T2*-weighted MR imaging at 1.5 and 3.0 T:early experience. Radiology. 2006 May; 239(2):481-7.

33. Hricak H, Choyke PL, Eberhardt SC, Leibel SA, Scardino PT. B Imaging prostate cancer: a multidisciplinary perspective. Radiology. 2007 Apr;243(1):28-53.
34. Contractor KB, Challapalli A, Sharma R,et al . Determination of pelvic node status in patients with high-risk localized or locally advanced prostate cancer by [11c]choline PET-CT. J Clin Oncol .2010;28 Suppl 15.
35. Salminen E, Hogg A, Binns D, et al. Investigations with FDG-PET scanning in prostate cancer show limited value for clinical practice. Acta Onco.l 2002;41(5):425-9.
36. Greco C, Cascini GL, Tamburrini O. Is there a role for positron emission tomography imaging in the early evaluation of prostate cancer relapse? Prostate Cancer Prostatic Dis. 2008;11(2):121-8.
37. Messiou C, Cook G, deSouza NM. Imaging metastatic bone disease from carcinoma of the prostate Br J Cancer. 2009 Oct 20;101(8):1225-32.