Section: Radiodiagnosis

Original Research Article

ROLE OF MULTIPARAMETRIC MRI IN EVALUATION OF CARCINOMA OF PROSTATE

Received : 22/01/2024
Received in revised form : 20/03/2024
Accepted : 05/04/2024

Keywords:
Prostate carcinoma, Multiparametric MRI, PI-RADS.

Corresponding Author:
Dr. Sweta Da Silva Pereira,
Email: sweta1985.sp@gmail.com

DOI: 10.47009/jamp.2024.6.2.168

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2024; 6 (2); 814-818

Visar Linyu[1], Renny Furtado[2], Sweta Da Silva Pereira[3], Yasmin Fernandes[4]

[1]Senior Resident, Department of Radiology, Goa Medical College and Hospital, Bambolim, Goa, India
[2]Associate Professor, Department of Radiology, Goa Medical College and Hospital, Bambolim, Goa, India
[3]Assistant Professor, Department of Radiology, Goa Medical College and Hospital, Bambolim, Goa, India
[4]Associate Professor, Department of Radiology, Goa Medical College and Hospital, Bambolim, Goa, India

Abstract

Background: Multiparametric MRI utilizes a combination of T1W, T2W, DWI/ADC, Dynamic contrast-enhanced MRI (DCE-MRI) and MRI spectroscopy to provide anatomic and functional assessment of the prostate. This study was aimed at evaluating the efficacy of multiparametric MRI in the detection of prostate carcinoma. **Materials and Methods:** Patients with raised PSA, BPH with rising PSA, abnormal digital rectal examination (DRE) findings and staging of known case of carcinoma prostate were enrolled in the study. MRI was performed on 1.5 Tesla (Magnetom Avanto, Siemens) using a surface coil. MRI sequences used in the study were T2 weighted imaging, T1 weighted imaging, DWI, MRI spectroscopy, T2 TIRM sequence and DCE-MRI. The study included 61 patients whose MRI findings were noted and followed up for the biopsy findings. **Result:** The sensitivity of T2W imaging was 89.3 % and specificity was 69.7 %. The sensitivity of DWI/ADC was 96.4 % and specificity was 72.7 %. The ability of DWI/ADC to detect prostate carcinoma was found to be statistically significant with a p- value <0.001. A combination of T2W imaging and DWI/ADC showed a sensitivity of 98.7 %, specificity of 66.7 % and accuracy of 85.6 %. The study showed a statistically significant relationship between low ADC values and higher Gleason scores of =7 or >7. The sensitivity and specificity of MRI spectroscopy alone was 84 % and 78.1 % respectively. The sensitivity of DCE-MRI was 70 % and specificity was 83.3 %. The combination of T2W and DWI/ADC with DCE-MRI showed a sensitivity of 70% and specificity of 87%. There was a positive correlation between the Gleason score and PI-RADS score with a P-value of 0.003. **Conclusion:** Multiparametric MRI using a combination of T2W imaging, diffusion weighted imaging, DCE-MRI and MRI spectroscopy provides an invaluable and non-invasive tool in the diagnosis of prostate carcinoma.

INTRODUCTION

Magnetic resonance imaging (MRI) provides high soft tissue contrast resolution and clear anatomical details and plays a key role in the diagnosis, staging and post-treatment follow-up of prostate cancer. Multiparametric MRI utilizes a combination of T1 weighted (T1W), T2 weighted (T2W) imaging, Diffusion weighted imaging/Apparent diffusion coefficient (DWI/ADC), Dynamic contrast-enhanced MRI (DCE-MRI) and MRI spectroscopy to provide anatomic, functional and physiological assessment of the prostate.

T1 weighted imaging

T1 weighted images are used primarily to delineate the gland and for detection of haemorrhage within the prostate gland and seminal vesicles which is common after biopsy and shows focal or diffuse hyperintensity on T1 weighted images.

T2 weighted imaging

T2W imaging is primarily utilized to discern gland anatomy, evaluate abnormalities within the gland, presence of extra-prostatic extension, seminal vesicle invasion and lymph nodal metastasis. T2 images have a high spatial resolution and can differentiate the intermediate to high signal intensity of the peripheral zone (PZ) of the prostate from the low signal intensity

ISSN (O): 2687-5365; ISSN (P): 2753-6556

of the central and transition zone (TZ). T2W images play a crucial role in characterizing abnormalities in the transition zone. The TZ is primarily assessed on T2W images and then correlated with DWI/ADC findings.[1] A malignant lesion on T2 weighted images has less well-defined margins and is often lenticular, irregular or conforming to a teardrop shape. A lesion which extends across the surgical capsule or into the fibromuscular stroma is highly suspicious for malignancy.[4,11]

ADC/DWI

Diffusion weighted imaging (DWI) is based on Brownian movement. Diffusion restriction is seen in tissues with high cellular density and intact cell membranes, like cancer, abscess, cytotoxic oedema and fibrosis. Based on DWI, the apparent diffusion coefficient (ADC) map can be calculated. ADC is expressed in mm^2/s and gives quantitative information that is inversely proportional to the degree of diffusion restriction. Low ADC values, appearing hypointense on the ADC map, represent tissues with restricted diffusion. Prostate carcinoma is histologically characterised by a high cell density and high nucleus/cytoplasm ratio than the normal tissue with replacement of glandular parenchyma by tumour cells. This causes a marked reduction in the ADC values, relative to the normal prostate. Prostate cancer foci are seen on DWI sequence as areas of restricted diffusivity (hyperintense signal), with corresponding hypointense signal on ADC maps.[2,12]

DCE-MRI

Dynamic contrast-enhanced MRI (DCE-MRI) is an important component of multiparametric MRI and is useful for evaluating the severity, location and extent of prostate cancer. DCE-MRI is acquired using T1 weighted gradient echo images following the administration of gadolinium-based contrast agent. Prostate carcinoma shows early and increased enhancement as compared to the surrounding normal prostatic parenchyma on DCE-MRI. This enhancement pattern is related to tumour angiogenesis. More aggressive tumours have the ability to initiate the production and release of angiogenic factors, such as vascular endothelial growth factor (VEGF). These tumour vessels show higher permeability than normal vessels, are more variable in size and more disorganized.[5,8]

MRI Spectroscopy

MR spectroscopic imaging (MRSI) is useful for evaluating the extent and aggressiveness of prostate cancer. The MR spectroscopic imaging box is prescribed on high-resolution axial T2W images and the metabolic information is then superimposed on the corresponding T2W images.[6] In prostate carcinoma, tumour cells utilize citrate in oxidizing metabolism. The high turnover of phospholipid raises the level of choline leading to an increased ratio of choline: citrate which can be used to detect malignancy. The mean normal (choline + creatine): citrate ratio is 0.22 ± 0.0013 with 1.5T.[3] A (choline + creatine): citrate ratio > 0.8 is very suspicious for prostate carcinoma while a ratio > 2 is considered abnormal. Polyamine levels are also reduced in prostate cancer.[9]

Metastasis

MRI has high sensitivity in the detection of bone metastases from prostate carcinoma. It can detect early changes in bone marrow that precede the osteoblastic response in the bone matrix. MRI has been shown to detect bone metastases in 37.5 % of patients with negative or inconclusive bone scan and plain films. MRI performs well in detecting metastasis to vertebral bodies which have large medullary cavities, in addition it can also detect tumour cells which may reside in-between the trabeculae.

Prostate imaging- reporting and data system (PI-RADS)

PI-RADS is a system used to standardize the acquisition, interpretation and reporting of prostate MRI examinations. The PI-RADS categories are based on the findings of T2W imaging, DWI and DCE-MRI. The PI-RADS assessment category determines whether clinically significant cancer is likely to be present in each lesion within the prostate gland, which is defined on pathology/histology as Gleason score > 7 and/or tumor volume > 0.5cc, and/or extraprostatic extension (EPE).

Gleason score

The Gleason scoring system is one of the most powerful prognostic predictors of prostate cancer. Five Gleason patterns were recognised on histopathology, which are then assigned a grade.[10] On core needle biopsy, the most prevalent pattern is graded as primary grade and any amount of the highest pattern is graded as secondary grade.[7] The pattern-number of the primary and secondary grades are summed up to obtain the final Gleason score. Gleason scores range from 2 to 10, with 2 representing the most well-differentiated tumors and 10 the least-differentiated tumors.

MATERIALS AND METHODS

This study was conducted on patients attending the urology OPD and referred for prostate MRI. Patients with raised Prostate-specific antigen (PSA), Benign Prostate Hyperplasia (BPH) with rising PSA, abnormal digital rectal examination (DRE) findings, and staging of known case of carcinoma prostate were included in the study. Patients with any contraindication to perform MRI such as cardiac pacemaker in situ, prosthetic heart valves, aneurysm clips, pelvic metallic implants and other ferromagnetic substances were excluded from the study. The study included 61 patients in which the clinical details with DRE findings, MRI findings and PSA values of patients were noted and followed up for the biopsy findings. MRI was performed on 1.5 Tesla (Magnetom Avanto, Siemens) using a surface coil. MRI sequences used in the study were T2 weighted imaging, T1 weighted imaging, DWI, MRI spectroscopy, T2 TIRM sequence and DCE-MRI.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

The T2 weighted abnormalities were classified as positive (malignant) or negative (benign). The findings on prostate MRI were also recorded as negative or positive for various tumour characteristics on T2W images including location, extracapsular extension, invasion of seminal vesicles, infiltration of neurovascular bundles, invasion of rectum and urinary bladder, presence of pelvic lymphadenopathy and distant metastasis. For DWI, findings were recorded using both diffusion images and ADC values. Lesions appearing hyperintense on DWI with corresponding low signal on ADC were considered malignant in this study. For MRI spectroscopy, tumour positive voxels on T2WI and DWI were selected for the study. Lesions showing increased choline + creatine/citrate ratio on MRI spectroscopy were considered positive for malignancy. The results of DCE-MRI were recorded as DCE positive or negative. Lesions showing focal and early enhancement and corresponding to a suspicious finding on T2W and/or DWI were considered DCE positive.

Statistical analysis

Statistical data analysis was done using Statistical Package for the Social Sciences (SPSS) 21.0 version. Unpaired t-test was done to compare two group means and ANOVA for more than two group means. Fisher's exact test or chi-square test was done to find out the association between categorical variables. To test the validity of a tool, sensitivity, specificity, Positive predictive value (PPV) and Negative predictive value (NPV) were calculated. P value of less than 0.05 was considered significant.

RESULTS

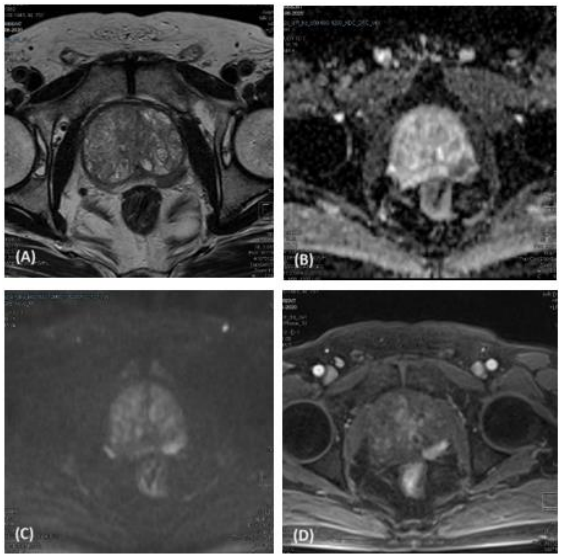

Figure 1: T2 weighted MRI image shows a hypointense lesion measuring 20 x 8.3 mm in the peripheral zone on the left side (A). Focal hypointensity was noted on ADC (B), appearing hyperintense on DWI (C). On DCE-MRI performed, early and focal enhancement of this lesion was noted (D). The lesion was classified as PI-RADS 3 with DCE +. Histopathology revealed Adenocarcinoma of prostate.

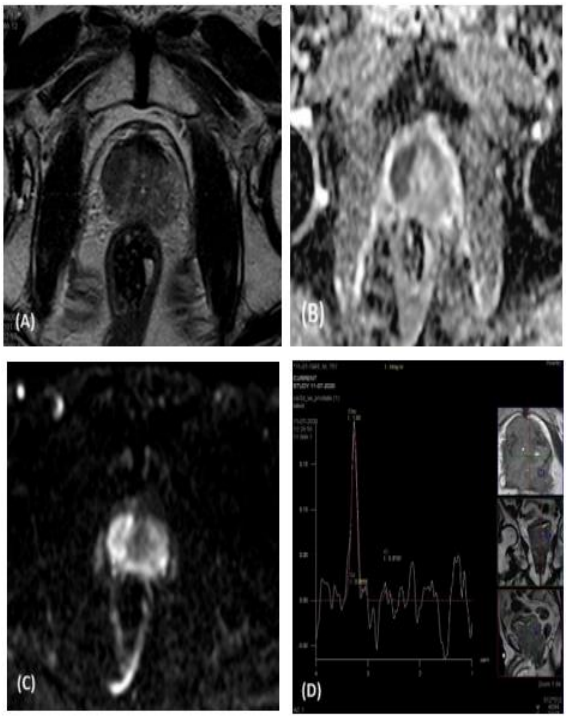

Figure 2: MRI images shows a well-defined T2 hypointense lesion in the peripheral zone on the right side measuring 17 x 15 mm(A). It shows marked hypointense signal on ADC (B) and markedly hyperintense signal on DWI (C). MRI Spectroscopy showed a choline peak (D). There was no extra-prostatic extension. The lesion was classified as PI-RADS 5. Histopathology revealed Adenocarcinoma of prostate.

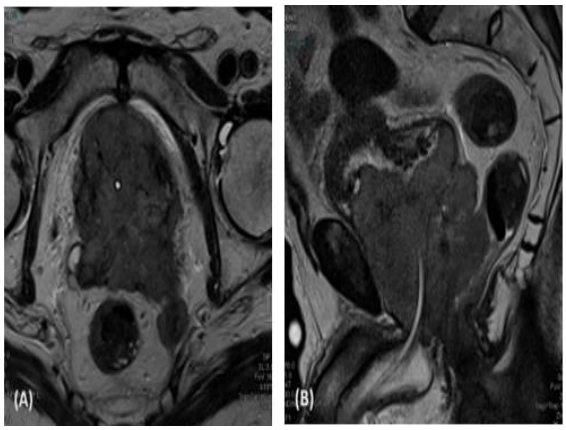

Figure 3: T2W axial (A) and T2W sagittal (B) images show an enlarged prostate gland (148 cc). The entire prostate gland is replaced by a T2 hypointense mass. Capsular breach with extraprostatic extension and involvement of bilateral seminal vesicles was noted. Fat planes with the base of bladder and anterior wall of rectum is lost. Infiltration of neurovascular bundle on the left side was noted. The lesion was classified as PI-RADS 5 (with extraprostatic extension). Histopathology revealed Adenocarcinoma of prostate.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Our study included 61 patients having an age range of 45 to 86 years. The mean serum PSA level of these patients was 45.12 ng/ml and the mean prostate volume was 58.67 cc. The number of patients showing positivity for malignancy on T2W imaging was 35 (57.4%), ADC/DWI was 36 (59%) and MR spectroscopy was 28 (49.1%). Out of 16 patients where DCE-MRI was performed, 8 showed positivity for malignancy. Subsequent biopsy showed malignancy in 28 patients (45.9%). The validity of MRI in correlation with prostate biopsy is shown in Table 1. On MRI, 32% of malignant lesions were located in the peripheral zone while 68% involved both peripheral and transition zones. Of the malignant lesions on MRI, extracapsular extension was present in 79% while distant metastasis was present in 50% of cases. The most frequent PI-RADS score in malignant lesions was PI-RADS 5 and the most frequent Gleason score in malignant lesions was Gleason score 8.

Table 1: Summary of sensitivity, specificity, PPV, NPV and accuracy of different MRI sequences in detection of prostate carcinoma

MRI sequence	Sensitivity	Specificity	PPV	NPV	Accuracy
T2W	89.3	69.7	71.4	88.5	78.7
DWI/ADC	96.4	72.7	75.0	96.0	83.6
MR spectroscopy (Ch+Cr:Ci)	84.0	78.1	75.0	86.2	80.7
DCE	70.0	83.3	87.5	62.5	75.0
T2W + DWI/ADC	98.7	66.7	71.1	95.7	85.6
T2W + DWI/ADC + (Ch+Cr:Ci)	80.0	93.8	90.9	85.7	87.7
T2W + DWI/ADC + DCE	70.0	87.0	87.5	62.5	75.0

Table 2: Comparison of mean ADC values (x 10^{-3} mm^2/s) with Gleason score

Gleason score	No. of malignant lesions	Mean ADC ±SD	P value
≤6	3	0.84 ± 0.02	<0.001
=7	6	0.74 ± 0.02	
>7	19	0.64 ± 0.02	

Table 3: Summary of relationship between PI-RADS score and Gleason score for malignant lesions

PI-RADS	Gleason score						P value
	≤6		=7		>7		
	No.	%	No.	%	No.	%	
3	1	33.3%	0	0.0%	0	0.0%	0.003
4	1	33.3%	2	33.3%	0	0.0%	
5	1	33.3%	4	66.7%	19	100.0%	

DISCUSSION

In our study of 61 patients, Transrectal ultrasound (TRUS) guided prostate biopsy showed malignancy in 28 patients and benign findings in 33 patients. Benign findings included BPH, prostatitis and BPH with prostatitis, with BPH constituting the majority of cases.

In our study, T2W imaging revealed features of malignancy in 35 out of 61 patients and benign findings in the remaining 26 patients. The sensitivity of T2W imaging was 89.3 % and specificity was 69.7 %. The PPV and NPV of T2W imaging was 71.4 % and 88.5 % respectively while accuracy was 78.7 % [Table 1]. Fusco et al reported similar findings with sensitivity of 75% and specificity of 60% for T2W imaging in the detection of prostate cancer.[15]

In our study, 36 cases showed diffusion restriction while 25 were negative for DWI. The ability of DWI/ADC to detect prostate carcinoma was found to be statistically significant with a p-value <0.001. Our study showed a high sensitivity of 96.4 % and specificity of 72.7 % for DWI/ADC alone [Table 1], which is comparable to a study by Taha Ali et al showing sensitivity, specificity, PPV and NPV of DWI/ADC alone to be 86.36%, 75% ,82.61% and 80% respectively.[13] Our study also showed a statistically significant relationship between low ADC values and higher Gleason scores of =7 or >7 [Table 2]. A similar inverse correlation between the ADC value and Gleason score was reported by Wu et al. Their study reported that the Gleason score 3 + 4 tumours had a lower minimum ADC value than the Gleason score 3 + 3 tumours in organ confined prostate cancer.[17] Thus, ADC values can be a useful marker of tumour aggressiveness with low ADC values correlating to a higher Gleason score.

A combination of T2W imaging and DWI/ADC showed a sensitivity of 98.7 %, specificity of 66.7 % and accuracy of 85.6 % [Table 1]. Thus, the diagnostic accuracy of combining T2W imaging and ADC /DWI was higher than T2W imaging or DWI/ADC alone. A recent meta-analysis on the diagnostic accuracy of T2W imaging combined with DWI, compared with T2W imaging alone showed similar findings with a higher diagnostic accuracy for T2W imaging combined with DWI than for T2 weighted imaging alone.[14]

Our study showed a sensitivity of 84 % and specificity of 78.1 % for MRI spectroscopy alone in the detection of prostate cancer. The combination of MRI spectroscopy with T2W imaging and DWI/ADC yielded a sensitivity of 80% and specificity of 93.8 % [Table 1]. Fusco et al showed

ISSN (O): 2687-5365; ISSN (P): 2753-6556

comparable results for MR spectroscopy with sensitivity of 89% and specificity of 69%.[15]

In this study, out of 16 cases in which DCE-MRI was performed 8 of the cases showed a positive DCE result. The sensitivity of DCE-MRI was 70 % and specificity was 83.3 % while a combination of T2W and DWI/ADC with DCE-MRI showed a sensitivity of 70% and specificity of 87 % [Table 1]. Previous studies have showed similar results for DCE-MRI with sensitivity and specificity ranges of 46–96% and 74–96%, respectively.[10]

Our study showed a positive correlation between the Gleason score and PI-RADS score [Table 3]. Katz et al also reported a significant relationship between a higher PI-RADS score and a finding of cancer on pathology.[16] This positive correlation shows the value of multiparametric MRI in characterizing the aggressiveness of the tumour.

CONCLUSION

Multiparametric MRI using a combination of T2W imaging, Diffusion weighted imaging, DCE-MRI and MR spectroscopy provides an invaluable and non-invasive tool in the diagnosis of prostate carcinoma. With the use of multiparametric MRI, there is a significant reduction in the number of unnecessary biopsies which could in turn prevent overdiagnosis and overtreatment. It also decreases the number of missed clinically significant cancers and improves risk stratification.

The positive correlation between an increasing PI-RADS score and increasing Gleason score shows that multiparametric MRI can non-invasively assess the tumour aggressiveness in prostate cancer. Similarly, the inverse correlation between tumour ADC values and Gleason score helps in determining the tumour aggressiveness.

Among the different techniques employed in this study, a combination of T2W imaging and diffusion weighted imaging provided the highest sensitivity while the highest specificity was obtained with a combination of T2W imaging, diffusion weighted imaging and MR spectroscopic imaging.

Thus, multiparametric MRI provides an excellent tool for the detection, characterization, staging, biopsy guidance and active surveillance of prostate cancer with a high degree of sensitivity and specificity.

REFERENCES

1. Prostate Imaging – Reporting and Data System, Version 2.1 (2019). American College of Radiology.
2. Hedgire SS, Oei TN, McDermott S, Cao K, Patel M Z, Harisinghani MG. Multiparametric magnetic resonance imaging of prostate cancer. Indian J Radiol Imaging. 2012 Jul;22(3):160-9. doi: 10.4103/0971-3026.107176. PMID: 23599562; PMCID: PMC3624737.
3. Males, R.G., Vigneron, D.B., Star-Lack, J., Falbo, S.C., Nelson, S.J., Hricak, H. and Kurhanewicz, J. (2000), Clinical application of BASING and spectral/spatial water and lipid suppression pulses for prostate cancer staging and localization by in vivo 3D 1H magnetic resonance spectroscopic imaging. Magn. Reson. Med., 43: 17-22. https://doi.org/10.1002/(SICI)1522-2594(200001)43:1<17::AID-MRM3>3.0.CO;2-6
4. Gupta RT, Spilseth B, Patel N, Brown AF, Yu J. Multiparametric prostate MRI: focus on T2-weighted imaging and role in staging of prostate cancer. Abdom Radiol (NY). 2016 May;41(5):831-43. doi: 10.1007/s00261-015-0579-5. PMID: 27193786.
5. Verma S, Turkbey B, Muradyan N, Rajesh A, Cornud F, Haider MA, Choyke PL, Harisinghani M. Overview of dynamic contrast-enhanced MRI in prostate cancer diagnosis and management. AJR Am J Roentgenol. 2012 Jun;198(6):1277-88. doi: 10.2214/AJR.12.8510. PMID: 22623539; PMCID: PMC6309691.
6. Verma S, Rajesh A, Fütterer JJ, Turkbey B, Scheenen TW, Pang Y, Choyke PL, Kurhanewicz J. Prostate MRI and 3D MR spectroscopy: how we do it. AJR Am J Roentgenol. 2010 Jun;194(6):1414-26. doi: 10.2214/AJR.10.4312. PMID: 20489079; PMCID: PMC2895419.
7. Iczkowski KA. Gleason grading. PathologyOutlines.com website. https://www.pathologyoutlines.com/topic/prostateGrading.html.
8. Nicholson B, Schaefer G, Theodorescu D. Angiogenesis in prostate cancer: biology and therapeutic opportunities. Cancer Metastasis Rev. 2001;20(3-4):297-319. doi: 10.1023/a:1015543713485. PMID: 12085968.
9. Kurhanewicz J, Swanson MG, Nelson SJ, Vigneron DB. Combined magnetic resonance imaging and spectroscopic imaging approach to molecular imaging of prostate cancer. J Magn Reson Imaging. 2002 Oct;16(4):451-63. doi: 10.1002/jmri.10172. PMID: 12353259; PMCID: PMC1978163.
10. Gleason DF, Mellinger GT. Prediction of prognosis for prostatic adenocarcinoma by combined histological grading and clinical staging. J Urol. 1974 Jan;111(1):58-64. doi: 10.1016/s0022-5347(17)59889-4. PMID: 4813554.
11. Rosenkrantz AB, Taneja SS. Radiologist, be aware: ten pitfalls that confound the interpretation of multiparametric prostate MRI. AJR Am J Roentgenol. 2014 Jan;202(1):109-20. doi: 10.2214/AJR.13.10699. PMID: 24370135.
12. Gibbs P, Pickles MD, Turnbull LW. Diffusion imaging of the prostate at 3.0 tesla. Invest Radiol. 2006 Feb;41(2):185-8. doi: 10.1097/01.rli.0000192418.30684.14. PMID: 16428991.
13. Taha Ali, T. F., ElHariri, M. A., & Riad, M. M. (2018). Diffusion-weighted MRI in prostatic lesions: Diagnostic performance of normalized ADC using normal peripheral prostatic zone as a reference. The Egyptian Journal of Radiology and Nuclear Medicine, 49(1), 239–244. doi:10.1016/j.ejrnm.2017.09.007
14. De Rooij M, Hamoen EH, Fütterer JJ, Barentsz JO, Rovers MM. Accuracy of multiparametric MRI for prostate cancer detection: a meta-analysis. AJR Am J Roentgenol. 2014 Feb;202(2):343-51. doi: 10.2214/AJR.13.11046. PMID: 24450675.
15. Fusco R, Sansone M, Granata V, Setola SV, Petrillo A. A systematic review on multiparametric MR imaging in prostate cancer detection. Infect Agent Cancer. 2017 Oct 30;12:57. doi: 10.1186/s13027-017-0168-z. PMID: 29093748; PMCID: PMC5663098.
16. Katz A, Liu C, Kosinski KE. Histopathologic correlation of PI-RADS V.2 lesions on 3T multiparametric prostate MRI. JCO 34, 10-10(2016). DOI:10.1200/jco.2016.34.2_suppl.10
17. Wu X, Reinikainen P, Vanhanen A, Kapanen M, Vierikko T, Ryymin P, Hyödynmaa S, Kellokumpu-Lehtinen PL. Correlation between apparent diffusion coefficient value on diffusion-weighted MR imaging and Gleason score in prostate cancer. Diagn Interv Imaging. 2017 Jan;98(1):63-71. doi: 10.1016/j.diii.2016.08.009. Epub 2016 Sep 27. PMID: 27687831.

ISSN (O): 2687-5365; ISSN (P): 2753-6556