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Original Research Article

Role of diffusion weighted MR imaging in differentiating benign from malignant prostate lesions

Sachin[1], Kirti Chaturvedy[1]*, R. N. Gehlot[1], Prateek Sihag[1], Suman Kumari[2], Anil Kumar Jangir[1], Mohit Jakhar[1], Ravindra Purohit[3], Tejinder Pal Singh[3]

[1]Department of Radiodiagnosis, [2]Department of Pathology, [3]Department of Urology, Dr. S. N. Medical College, Jodhpur, Rajasthan, India

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***Correspondence:**
Dr. Kirti Chaturvedy,
E-mail: sachinsura0009@gmail.com

ABSTRACT

Background: The purpose of the study was to determine the diagnostic accuracy of diffusion weighted MR imaging and to propose a cut off ADC value in differentiating benign from malignant prostatic lesions considering histopathology as gold standard.
Methods: It is a descriptive type of observational study done on 40 patients with clinical suspicion of prostate carcinoma and elevated PSA level more than 4ng/ml. The patients underwent Multiparametric prostate MRI and ADC values were calculated using ADC maps.
Results: Of the 40 cases included in the study histopathology revealed a diagnosis of abscess (1), chronic prostatitis (2), BPH with chronic prostatitis (4), BPH (12), and malignancy (21). The mean and standard deviation (SD) of ADC values for the abscess (0.59), CP (0.83$\pm$0.16), BPH with CP (0.94$\pm$0.22), BPH (1.14$\pm$0.14) and malignancy (0.72$\pm$0.15) ($x10^{-3}mm^2/s$) were found in our study. The mean ADC value of malignant lesion was lower (0.727$\pm$0.149) as compare to benign lesion (1.034$\pm$0.216) and this difference was found to be statistically significant with $p<0.001$. By using ROC curve, ADC cut off value was calculated as 0.92 x $10^{-3}mm^2/s$ and sensitivity, specificity at this cut off value of ADC were 95.24% and 73.68% respectively. The PPV, NPV, diagnostic accuracy of at this cut off value of ADC were 80%, 93.33%, 85% respectively.
Conclusions: Our study shows that DWI with ADC calculation helps in differentiation of Benign from Malignant prostatic lesions with high accuracy and this quantitative analysis should be incorporated in routine MRI evaluation of prostatic lesions.

Keywords: Apparent diffusion coefficient, Diffusion weighted imaging, Magnetic resonance imaging, Prostate carcinoma

INTRODUCTION

Prostate cancer is a major public health problem and the exploration of noninvasive imaging methods that have the potential to improve specificity, while maintaining high sensitivity is still critically needed. The radiological challenge is to provide an assessment of the anatomical, physiological, functional, and metabolic activity of prostate and surrounding tissue for increased accuracy of diagnosis before and after treatment. Such radiological biomarkers are under investigation, for example magnetic resonance (MR) imaging with T2-weighted imaging (T2WI), diffusion-weighted imaging (DWI), magnetic resonance spectroscopy (MRS), and dynamic contrast enhanced MR imaging (DCE-MRI). These various MR

parameters are increasingly being utilized in a multi parametric paradigm for imaging of the prostate.[1]

DRE is anatomically limited to the posterior and lateral aspects of the prostate gland only, so it decreases sensitivity of the examination.[2]

The advent of ultrasonography in medical imaging revolutionized imaging of prostate as it is used for direct visualization of prostatic pathologies. But its operator dependence, lack of specificity and poor characterization and localization of lesions are its main drawbacks.

Multidetector Computed Tomography (MDCT) studies shows the value in demonstrating enlarged gland size and abscess cavity, but it cannot differentiate benign from malignant lesions on the basis of size alone.

MRI is a competitive and comprehensive modality for assessing the morphology and functional characteristics of the prostate in cases of diffuse and focal prostatic disease.

On T2-WI, prostate cancer usually demonstrates low signal intensity in contrast to the high SI of the normal peripheral zone. Low SI in the peripheral zone, however, can also be seen in several benign conditions, such as hemorrhage, prostatitis, hyperplastic nodules, or post treatment sequelae.[3]

Based on recent advances in MRI technique, diffusion-weighted imaging (DWI) has been applied to prostate examinations. Diffusion weighted imaging (DWI) is another mechanism for developing image contrast and relies on changes in the diffusion properties of water molecules in tissues.

Recent hardware and software improvement allow the expanded use of functional MRI techniques including Diffusion Weighted Images (DWI) for the differentiation of cancer tissue from non-cancerous tissue.[4] It is on the fact that cancer tissue generally tends to have more restricted diffusion than non-cancerous tissue because of its high cell densities and abundant intra- and inter-cellular membranes.[5]

DWI assesses the Brownian motion of free water in tissue. In tumors, the motion of water is restricted, probably due to their higher cellular density and increased nucleo-cytoplasmic ratio, and it can be depicted on ADC maps, permitting a quantitative evaluation.[6] The use of DWI enables the calculation of the apparent diffusion coefficient (ADC), which is a value that measures water diffusion in tissues. The movement of water is restricted by movement in tumors, leading to a reduction in the ADC value.[7]

Diffusion weighted MR imaging provides a tool to characterize prostatic lesions without the risk of contrast agents and exposure to ionizing radiation.

Diffusion-weighted imaging and ADC have become powerful indicators for characterization of prostatic tissue, particularly in differentiation between benign and malignant lesions.[8]

The ADC value as a quantitative parameter of DWMRI represents the magnitude of molecular movement in biological tissues. The restriction of diffusion results in decreased ADC values on ADC maps generated from DW images. There is significant difference between ADC values of prostate cancer and benign prostate lesions. The ADC values of cancerous lesions have been found lower than normal parenchyma of prostate. The sensitivity and specificity of DWMRI for prostate cancer detection were reported as 57-93.3% and 57-100%, respectively.[9]

In our study we used to PIRADS v2 for assessment of prostatic lesions on MR imaging.[10,11]

This study is aimed at determining the role of diffusion weighted MR imaging of prostate in the detection, characterization of prostatic lesions and to differentiate benign from malignant lesions by using their ADC values. Also, to find out diagnostic efficacy of diffusion weighted MR imaging in differentiating benign from malignant prostate lesions by histopathological correlation as gold standard.

METHODS

The study was carried out on 42 patients in department of radiodiagnosis at Dr. S. N. Medical college, Jodhpur, Rajasthan and attached hospitals over a period of 12 month. All the MR Imaging in this study was performed using 1.5-T scanner (PHILIPS, Achieva, The Nederlands) with PHILIPS intellispace portal, windows workstation and software. External surface coil was placed over the pelvic region for study.

Patients who had hard prostate on DRE, lower urinary tract symptoms and elevated PSA level more than 4 ng/ml were included in the study group.

Excluded patients

Who were post hormonal/radiotherapy, had undergone prostatic biopsy less than 6 weeks before the MRI, on MR imaging-haemorrhagic area in prostate, mass lesions infiltrating the prostate from outside, general contraindication to MRI such as those with pace makers, cochlear implants and other electromagnetic implants in the body, claustrophobia etc and who refused to signed informed consent form.

Pulse sequences and imaging planes

A three-plane localizer was obtained for planning of the various sequences. A T2W fast spin-echo was obtained in the sagittal, coronal and axial plane. A T1W fast spin-echo was obtained in the axial plane. This was followed

by DWI obtained through a multi section spin-Echo single shot echo planar sequence in the transverse plane, using b values of 0 and 1000 sec/mm^2. A T2W fat suppressed was obtained in axial plane.

Analysis of ADC was an automated process, available as an application in our scanner. Calculation of ADC was made for each voxel of an image and was displayed as a parametric (ADC) map. ADC measurements was then recorded for a given region by drawing regions of interest (ROI) on the ADC map. An average of three ADC values were taken of index lesion for calculation of mean ADC value.

The prostate was viewed in T1W, T2W, T2W SPAIR and DWI sequences and abnormalities were identified. When multiple lesions were noted, the most representative lesion or the largest lesion was taken into consideration.

Statistical analysis

Data was analyzed by taking cut off value of ADC 0.8, 0.9, 1 and 1.1 (x 10^{-3} mm^2/sec) and correlate the specificity and sensitivity of each cut off.

After taking out mean ADC values of lesions comparison was done before ADC value of benign, malignant lesions and correlated mean ADC value with PIRADS score. The final MRI diagnosis was made by MRI+DWI+ADC value findings. These findings were then tabulated and correlated with the histopathological diagnosis of the lesion.

RESULTS

This study was carried out in the department of radio-diagnosis, Dr. S. N. medical college Jodhpur, Rajasthan, India. Total number of 42 patients were included in the study, however 2 patients were lost to follow up and their histopathology reports were not available so for statistical analysis and results 40 patients taken (n=40).

Patients age was ranging between 54 years to 94 years. In this study, majority of the patients belonged to the age group more than 70 years constituting 62.50%. Of the total patients a benign etiology was confirmed on histopathology in 47.5 % of the cases and included:

Prostate abscess appearing multiloculated lesion involving both PZ and TZ, showing diffusion restriction, On ADC images reduced ADC values (mean ADC value of 0.59 x10^{-3} mm^2/sec), T1FS contrast image showing diffuse peripheral enhancement with non-enhancing central area, note that no enhancement is present in area showing diffusion restriction (Figure 1).

Chronic prostatitis with BPH appearing diffuse abnormality in form of hypo-intensity on T1Wi, multiple areas of T2 hypointensity in transitional as well as peripheral zone, irregular shape and indistinct margins in the background of organized chaos, On DWi Mild to moderate diffusion restriction with corresponding low ADC (0.86 x10^{-3} mm^2/sec) consistent with PIRADS score 4 (Figure 2).

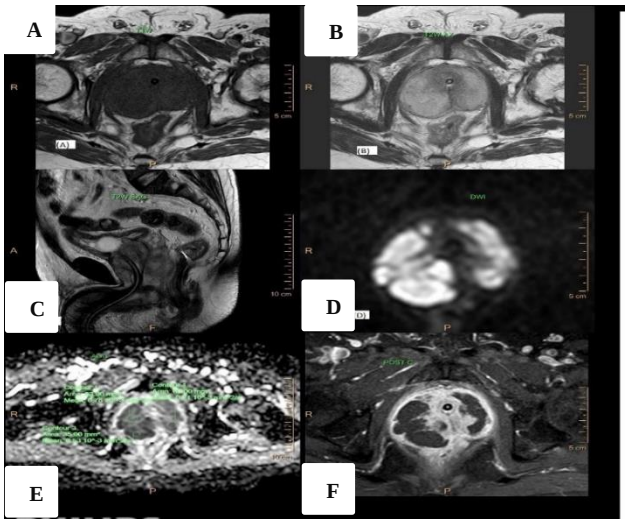

Figure 1: MRI of patient of prostatic abscess, (A) Hypo-intense on T1Wi, (B, C) Hyperintense on T2Wi, (D) DWI showing diffusion restriction, (E) corresponding reduced ADC value, (F) T1FS contrast image showing diffuse peripheral enhancement with non-enhancing central area.

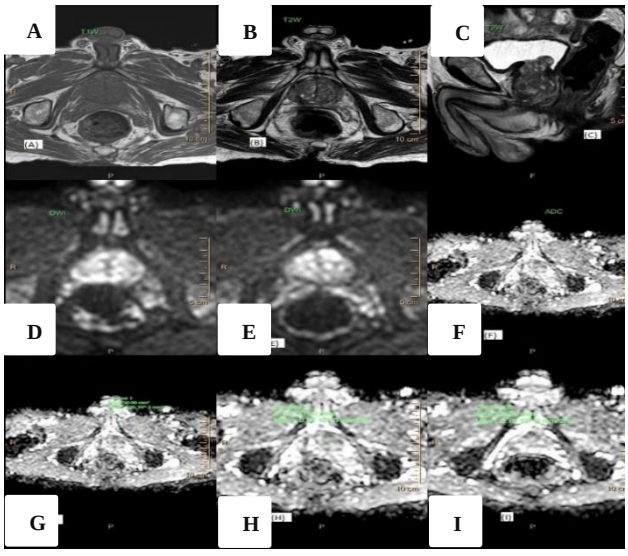

Figure 2: Patient of chronic prostatitis with BPH, (A) Hypo-intensity on T1Wi, (B, C) Multiple areas of T2 hypointensity in the background of organized chaos, (D, E) On DWI Mild to moderate diffusion restriction, (F to I) Corresponding low ADC values.

BPH appearing enlarged transitional zone with heterogenous signal intensity on T2Wi. No diffusion restriction and corresponding ADC map images show mean ADC value of 1.32 x10^{-3} mm^2/sec. PIRADS score was 2 (Figure 3).

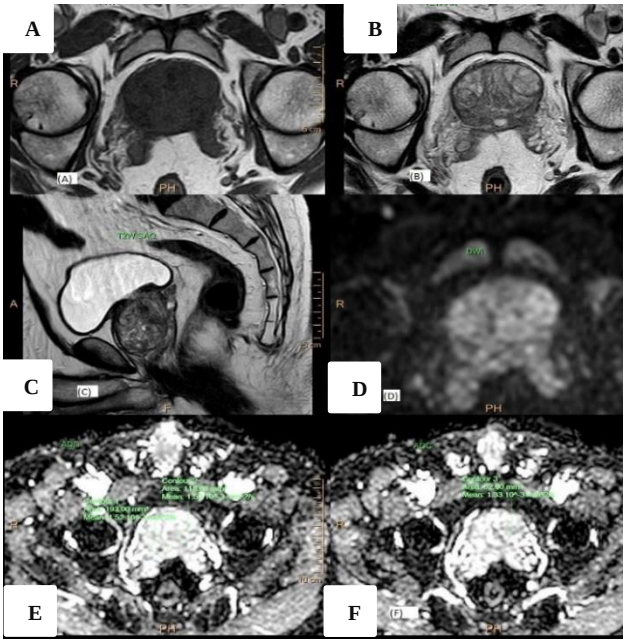

Figure 3: MRI of BPH, (A) Hypo-intense on T1Wi, (B, C) Enlarged transitional zone with heterogenous signal intensity on T2Wi, (D) On DWi, no diffusion restriction, (E, F) Corresponding ADC map images show intermediate signals.

A malignant etiology was found in 52.5 % of the patients and included:

Adenocarcinoma diffusely involving TZ and PZ and appearing hypo-intense on T1Wi, Multifocal abnormality in form of irregular shaped, indistinct marginated hypointensity on T2Wi in peripheral zone as well as transitional zone of base, mid and apex of prostate, largest lesion measuring ~13x9x10 mm, On DWi, showing diffusion restriction with corresponding low ADC (mean ADC 0.49 $x10^{-3}$ mm^2/sec). PIRADS Score was 5. Adenocarcinoma diffusely involving both zones PZ and TZ (Figure 4).

Adenocarcinoma involving PZ and showing multifocal abnormality in form of hypo-intense on T1Wi, irregular shaped, indistinct marginated T2 hypointensity in peripheral zone of base, mid and apex of prostate, largest lesion measuring ~20x31x31 mm, On DWi, showing diffusion restriction with corresponding low ADC (mean ADC of 0.45 $x10^{-3}$ mm^2/sec). The lesion had ECE+. PIRADS Score was 5 (Figure 5).

Most of the benign lesions (52.64%) were present in transitional zone and malignant lesions were more commonly present in peripheral zone. 47.62% of prostate cancers diagnosed by HPR (histopathology reports) were localized in peripheral zone, 09.53% were localized in transitional zone and 42.85% were localized in peripheral plus transitional zone. These results were statistically significant (P value=0.002).

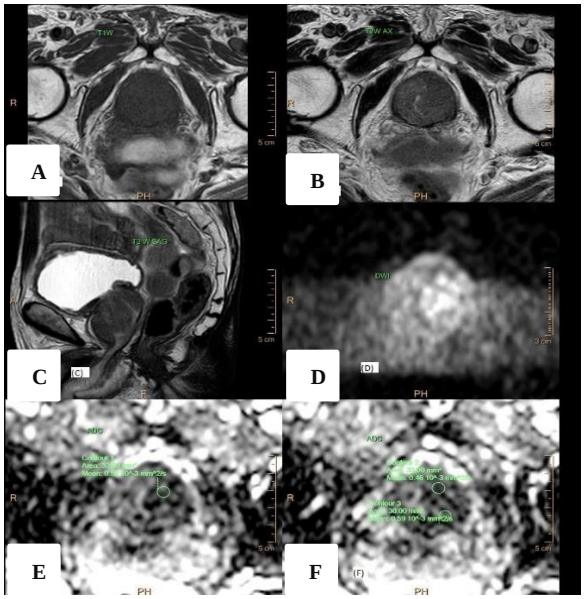

Figure 4: MRI of TZ and PZ adenocarcinoma, (A) Hypo-intense on T1Wi, (B, C) Multifocal hypointensity on T2Wi in peripheral zone as well as transitional zone, (D) On DWi, showing diffusion restriction, (E, F) Low ADC values.

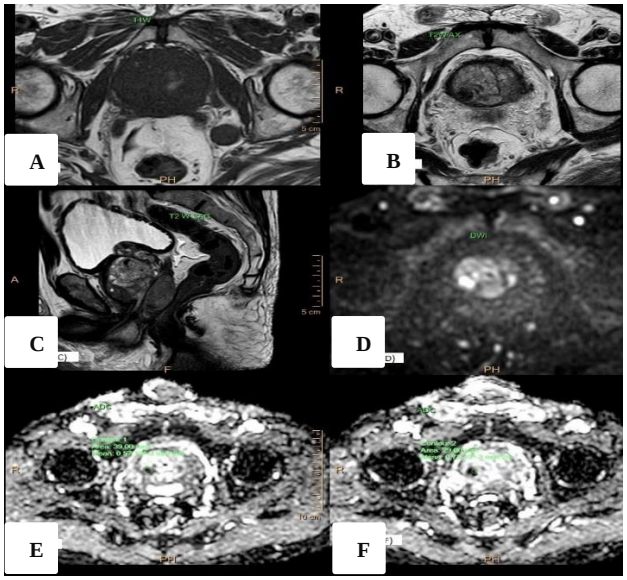

Figure 5: Patient of PZ adenocarcinoma, (A) Hypo-intense on T1Wi, (B, C) T2 hypointensity in peripheral zone, (D) On DWi, showing diffusion restriction, (E, F) low ADC values and extracapsular extension.

In benign lesions which showed diffusion restriction had inflammatory properties confirmed on HPR. Study reveals lesions that were showing diffusion restriction have 95.24% sensitivity to detect malignancy and 66.67% PPV, 90% NPV correlated with HPR. Our diagnostic accuracy of diffusion weighted MR imaging was 72.5% correlated with HPR (Table 1).

Table 1: Appearances of the lesions on DW sequence in relation to HPR (n=40).

DWI	HPR				Total	
	Malignant		Benign			
	No.	%	No.	%	No.	%
Hyperintense	20	95.24	10	52.63	30	75.00
Hypointense	1	04.76	9	47.36	10	25.00
Total	21	100.00	19	100.00	40	100.0

*Hyperintense on DWI-who are showing diffusion restriction with corresponding low ADC

In this study majority of patients (45%, 18/40) were in range of 4 to 25 ng/ml PSA value, these patients' group of mean ADC value was 1.03, out of them 16.67% (3/18) malignant on HPR and 83.33% (15/18) benign on HPR. 22.5% (9/40) patients had PSA value range was 26 to 50 ng/ml (mean ADC value 0.82), out of them 66.67% (6/9) malignant on HPR and 33.33% (3/9) benign on HPR. 32.50% (13/40) patients had more than 50 ng/ml PSA value (mean ADC value 0.68), out them 92.30% (12/13) were malignant on HPR and 07.70% were benign on HPR. So, if PSA value increase then mean ADC value decreases which indicate more risk towards malignancy. These results were show moderate negative correlation between PSA and mean ADC value and it was statistically significant (P value <0.001). Patients who had more than 50 ng/ml PSA value, had 92.30% chances of malignancy, those in 26-50 ng/ml PSA value range there was 66.67% chances of malignancy and in 4 to 25 mg/ml PSA value range, 16.67% chances of malignancy (Table 2).

Table 2: Correlation between PSA and ADC.

Correlation coefficient	-0.510 (Moderate negative correlation)
P value	<0.001 (S)

Table 3: Association amongst zonal distributions of benign (19) and malignant (21) lesions with mean ADC value (n=40).

Zonal distribution of malignant lesions	No. Of cases (Total=21)	Mean ADC Value (x 10^{-3}mm^2/s)	Zonal distribution of benign lesions	No. of cases (Total=19)	Mean ADC value (x 10^{-3}mm^2/s)
Peripheral	10	0.68	Peripheral	1	1.06
Transitional	2	0.84	Transitional	10	1.10
BOTH (P+T)	9	0.73	BOTH (P+T)	8	0.94

* Mean ADC value calculated by adding the ADC values of 'n' patients and dividing it by 'n'

Table 4: Comparison of diagnosis on final PIRADS score with histopathology follow up (n=40) Chi-square = 22.528 at 4 df; P<0.001 (S).

Final PIRADS score	HPR		Total Cases	Mean ADC Value (x 10^{-3}mm^2/s)
	Malignant	Benign		
1	0	1	1	1.25
2	0	5	5	1.43
3	0	6	6	1.06
4	8	6	14	0.84
5	13	1	14	0.70

*Mean ADC value calculated by adding the ADC values of 'n' patients and dividing it by 'n'

Lesions in peripheral zone on HPR had low ADC values as compare to transitional zone lesions (Table 3).

Our results were showed when PIRADS score increases then mean ADC value significantly decreases (P value <0.001). Mean ADC values of abscess (0.59), CP (0.83±0.16), BPH+CP (0.94±0.22), BPH (1.14±0.14) and malignancy (0.72±0.15) (x 10^{-3} mm^2/s) were found in our study (Table 4).

Patients diagnosed as having benign and malignant pathology on histopathology in our study, had a mean ADC value of 1.034±0.216x10^{-3} mm^2/s and 0.727±0.146 x 10^{-3} mm^2/s respectively. So, above table depicts that the mean ADC of Malignant lesion was lower (0.727) as compared to Benign lesion (1.034) and this difference was found to be statistically significant with p<0.001 (Table 5).

In this study, by using ROC curve, ADC cut off value was calculated as 0.92x10^{-3} mm^2/s for deafferenting benign vs malignant lesion. Sensitivity, specificity at this cut off value of ADC were 95.24% and 73.68% respectively. The PPV, NPV, diagnostic accuracy of at this cut off value of ADC were 80%, 93.33%, 85% respectively (Table 6).

Comparing quantitative evaluation by ADC cut off calculation and subjective evaluation by DW images the accuracy and specificity of quantitative evaluation by ADC cut off at 0.92 (by ROC curve) was more 85% and 73.68% respectively compared to DW images accuracy and specificity 72.5% and 47.37% respectively. Also, with cut off ADC at 0.92 (by ROC curve) the sensitivity compare to DWI was same (95.24%). So, By ADC cut off value malignancy prediction and accuracy were increased, hence ADC by quantitative method is better than subjective evaluation by diffusion weighted imaging for calculation of risk of malignancy (Table 6).

Table 5: Comparison of ADC value of benign and malignant lesions diagnosed by HPR (n=40).

	No. of cases	Mean ADC value ($x10^{-3}mm^2/s$)	SD	p value*
Benign	19	1.034	0.216	<0.001
Malignant	21	0.727	0.149	

*Mean ADC value calculated by adding the ADC values of 'n' patients and dividing it by 'n'

Table 6: At cut off 0.92 (by ROC curve) for diagnosis of malignant and benign lesion.

ADC	HPR				Total	
	Malignant		Benign			
	No.	%	No.	%	No.	%
≤0.92	20	95.24	5	26.31	25	62.50
>0.92	1	04.76	14	73.68	15	37.50
Total	21	100.00	19	100.00	40	100.00

DISCUSSION

Diffusion-weighted imaging and ADC have become powerful indicators for characterization of prostatic tissue, particularly in differentiation between benign and malignant lesions.[8] Prostate carcinoma is histologically characterized by a higher cellular density than normal prostate tissue, with replacement of the normal glandular tissue; thus, it is expected to show a more impeded diffusion of water molecules, compared with normal prostatic gland.[12]

In present study, high b value (1000 s/mm^2) was used for 1.5 tesla MRI machine. Esen M et al, had obtained ADC values of 50 patients at b value 100, 600 and 1,000 s/mm^2 diffusion gradients with 1.5 T MRI.[10] They had concluded that, DWI with ADC measurement may be used as a complementary imaging method in differentiation of prostate cancer from normal prostate parenchyma and prostatitis at intermediate and high-level diffusion gradients. This finding was similar to our study for b value 1000 s/mm^2 diffusion gradients.

In present study lesions were identified using T2W and DWI sequences. Then, the lesions were characterized based on their appearance in these sequences and ADC values of these lesions were calculated from the corresponding ADC maps (mean ADC value). After taking out mean ADC values of lesions comparison was done before ADC value of benign, malignant lesions and correlated mean ADC value with PIRADS score. The final MRI diagnosis was made by MRI+DWI+ADC value findings and compared with HPR as gold standard.

In present study 11 patients (27.50%) had lesion in peripheral zone, 12 patients (30.00%) had lesion in transitional zone and 17 patients (42.50%) had lesion in both peripheral and transitional zone on MRI. Our results were in concordance with results of study carried out by Lee CH et al.[13] On HPR, out of total 40 patients, 21 (52.50%) patients were diagnosed as prostatic cancer (which were more commonly in peripheral zone), 12 (30%) patients were diagnosed as BPH (present in transitional zone), 4 (10%) patients were diagnosed as BPH with chronic prostatitis, 2 (05%) cases were diagnosed as chronic prostatitis and 1 (02.5%) case was diagnosed as abscess. Anunobi CC et al, had observed in their study that most hyperplasia occurs in transitional zone while most carcinoma originates in the peripheral zone.[14] Most frequently encountered diseases affecting prostate are prostatitis, benign prostatic hyperplasia and prostatic cancer. These findings were in concordance with our study findings.

In our study, 47.62% (10/21) of prostate cancer diagnosed by HPR were localized in peripheral zone, 9.53% (2/21) were localized in transitional zone and 42.85% (9/21) were localized in peripheral+ transitional zone. Muhammed AB et al had observed that in approximately, 70% of prostate cancer cases arise in the peripheral zone of gland particularly in the posterior location.[15] These findings were in concordance with our study findings.

In present study malignant lesions which were in peripheral zone (47.61%) had low ADC value (mean ADC value 0.68) as compare to transitional zone (09.52%) malignant lesions (mean ADC value 0.84).

In our study, 1 patient had PIRADS-1 lesion (100% cases were benign on HPR: BPH). 5 patients had PIRADS-2 lesions (100% cases were benign on HPR: -BPH), 6 patients had PIRADS-3 lesions (100% cases were benign on HPR: 4 BPH, 1 CP, 1 BPH+CP). 14 patients had PIRADS-4 lesions (42.85% cases were benign '1 CP, 2 BPH, 3 BPH+CP' and 57.14% cases were malignant on HPR). 4 patients had inflammatory properties on HPR, so these lesions were showing diffusion restriction with corresponding low ADC value, so these lesions had high PIRADS score-4. 2 patents were diagnosed on HPR as benign prostatic hypertrophy (BPH), these lesions were present in transitional zone, had indistinct margin on T2W (hypointense), so these lesions were consistent with PIRADS 4 score. 14 patients had PIRADS-5 lesions 07.15% (1) cases were benign and 92.85% (13) cases are malignant on HPR). In this study on HPR one case was abscess (benign) which was in PIRADS-5 on MRI+DWI, however on post contrast study the lesion was showing peripheral enhancement with central diffusion restriction consistent with abscess, so on MRI we characterized the lesion diagnosed it as benign despite PIRADS score of 5. It was the confounding factor for PIRADS scoring.

All lesions irrespective of their nature had hypointense signal on T1W images, thus implying the fact that T1W sequence is not useful for characterization of prostatic lesions as benign and malignant. This was in concordance with observations made by Claus FG et al.[3]

Appearances of the lesion on T2W images were hypointense in signal intensity constituting 97.50%, while hyperintense signal constituting 02.50% of lesions. 97.50% lesions diagnosed as benign and malignant on HPR was hypointense on T2W. So, lesion localization using T2 weighted imaging demonstrated overestimation of malignancy presence. This is most likely due to the difficulty in identifying malignancy separate from benign lesion. Hence, diffusion weighted images compare to T2W were more specific and accurate. Claus FG et al, observed that on T2W images cancer usually demonstrates hypointense signal intensity, however hypointense signal intensity may also be found in several benign conditions, such as hemorrhage, prostatitis, hyperplastic nodules, or post treatment sequelae (e.g. as a result of irradiation or hormonal treatment).[3] Hyperintense signal on T2W was produced only by prostate abscess. Mean ADC values within the abscess was very low (0.59 in our study). This could be confused with malignancy but on contrast study and T2 signal intensity helped in differentiating two.

In our study 95.24% of the total malignant lesions and 52.63% of the total benign lesions which were diagnosed on HPR showed diffusion restriction (hyperintense). Benign lesions which were showing diffusion restriction had inflammatory properties on HPR. Lesions who were showing diffusion restriction had 95.24% sensitivity to detect malignancy and 66.67% PPV, 90% NPV correlated with HPR. Our diagnostic accuracy of diffusion weighted MR imaging was 72.5% correlated with HPR. This results sensitivity was higher than previous study result of Jagannathan D et al.[16]

Patients diagnosed as benign pathology on histopathology in our study, had a mean ADC value of $1.034\pm0.216 \times 10^{-3}$ mm^2/s and patients with malignant pathology had a mean ADC value of $0.719\pm0.149 \times 10^{-3}$ mm^2/s. So, the mean value of ADC in malignant lesion was significantly lower than that of benign lesions. On application of statistical test, this difference was significant with p value <0.001. This was in agreement with the previous reports of Yagci AB et al who had reported mean ADC value of malignant and benign lesion was 0.94 and 1.58 respectively.[6]

In present study, mean ADC value for BPH was $1.14\pm 0.14\times10^{-3}$ mm^2/s. This result was slightly lower than results of Emad-Eldin S et al and Xiaohang Liu et al who reported that the mean ADC value of benign prostatic hyperplasia was $1.359\pm0.201\times10^{-3}$ mm^2/s. and $1.21\pm0.21\times10^{-3}$ mm^2/s respectively.[17,18] Mean ADC value for prostate carcinoma was $0.72\pm0.15 \times 10^{-3}$ mm^2/s. This was in agreement with previously reported by Abdel-Maboud NM, et al who found that mean ADC value of 31 cases of prostate carcinoma was $0.73 \pm 0.15 \times 10^{-3}$ mm^2/s.[19] Mean ADC value for prostate carcinoma in our study were lower than results of Tanimoto A et al and Emad-Eldin S et al who reported that a mean ADC value of prostatic carcinoma was $0.93\pm0.16 \times 10^{-3}$ mm^2/s and $0.93\pm0.11\times10^{-3}$ mm^2/s respectively.[20,17] Mean ADC value for chronic prostatitis was $0.83\pm0.16 \times 10^{-3}$ mm^2/s. Only one case was diagnosed as a prostatic abscess on HPR which had ADC value of 0.59. This was in agreement with previous results of Ren J et al who observed that mean ADC value for prostatic abscess was $0.618\pm0.192 \times 10^{-3}$ mm^2/s.[21]

In our study, by using ROC curve, area under the ROC curve was 0.884 and best ADC cut off value was calculated as 0.92×10^{-3} mm^2/s which was used to differentiate benign from malignant lesion which provided 95.24% sensitivity, 73.68% specificity and 85% diagnostic accuracy. The PPV, NPV at this cut off value of ADC were 80%, 93.33%, respectively. PPV value of quantitative ADC measurements was lower due to inflammatory lesions (low ADC value) appearing false positive for cancer. However, NPV of quantitative ADC measurements with cut off at 0.92 is very high 93.33% indicating that when resources are readily available DWI with ADC measurements can be used for screening of prostate cancer.

Cut off value of ADC (0.92) observed in our study by ROC curve to differentiate benign from malignant

prostate lesion was lower than the value of ADC 1.35 observed in previous study of Nagayama M et al and to value of ADC 1.2 observed by Yagcı AB et al.[22,6] Our results were in concordance with those of the previous study of Emad-Eldin S et al who had reported that the sensitivity, specificity and diagnostic accuracy were 85%, 95% and 90% with cut off value of $0.93x10^{-3}$ mm^2/s.[17]

Specificity and diagnostic accuracy of our study for prostate cancer localization was similar to those of the previous study of AbdelMaboud NM et al who have reported specificity and diagnostic accuracy of 71% and 83% respectively.[19] But Sensitivity of our study for prostate cancer (95.24%) was higher to the previous study of AbdelMaboud NM et al who have reported sensitivity 86%.[19]

When quantitative evaluation by ADC with cut off at 0.92 was compared with subjective evaluation by DW images the sensitivity of both techniques same that was 95.24%. however, the accuracy and specificity of quantitative evaluation by ADC with cut off at 0.92 was more 85% and 73.68% respectively compared to accuracy and specificity of DW images 72.5% and 47.37% respectively. So, By ADC cut off value malignancy prediction and accuracy were increased, hence ADC by quantitative method is better than subjective evaluation by diffusion weighted imaging for calculation of risk of malignancy.

Thus, our study had shown that DWI with ADC value plays an important role in localization, characterization and differentiation of prostate lesions as benign and malignant.

In our study we observed that when PSA value of patients rises then ADC value of lesions decreases which indicates more risk towards malignancy. Majority of patients (45%, 18/40) were in range of 4 to 25 ng/ml PSA value, these patients' group of mean ADC value was 1.03, out of them 16.67% (3/18) malignant on HPR and 83.33% (15/18) benign on HPR.

There were 22.5% (9/40) patients had PSA value range was 26 to 50 ng/ml (mean ADC value 0.82), out of them 66.67% (6/9) malignant on HPR and 33.33% (3/9) benign on HPR. There were 32.50% (13/40) patients had more than 50 ng/ml PSA value (mean ADC value 0.68), out them 92.30% (12/13) were malignant on HPR and 07.70% were benign on HPR. So, if PSA value increase then mean ADC value decreases which indicate more risk towards malignancy. These results were show moderate negative correlation between PSA and mean ADC value and it was statistically significant (P value <0.001).

In this study, patients had more than 50 ng/ml PSA value, 92.30% chances of malignancy, in 26-50 ng/ml PSA value range there was 66.67% chances of malignancy and in 4 to 25 mg/ml PSA value range, 16.67% chances of malignancy. Bannakij L et al reported that the specificity of PSA levels of 4.1-10, 10.1-20, 21.1-50, 50.1-100 and >100 ng/ml in the diagnosis of prostate cancer was 9.3, 55.5, 87.5, 98.2 and 99.7% respectively.[23] These results were in concordance with our study.

These statistical results of DWI with ADC measurements for distinguishing between benign and malignant prostatic lesion has potential of greatly reducing un-necessary biopsy. It can accurately localize prostatic cancer and help targeted biopsy, which will have higher detection rate then sextant conventional biopsy.[20]

Clinical application

MR evaluation of prostate is an excellent non-invasive investigation to differentiate benign from malignant lesions. Best characterization of lesions and calculation of PIRADS score results from mpMRI which must include DWI with ADC calculation. It helps to reduce the number of biopsies in patients. MR imaging gives excellent tumor localization and staging of disease which is helpful in planning of biopsy, surgery and post treatment follow up.

CONCLUSION

Our study shows that DWI with ADC calculation helps in detection and characterization of Benign and Malignant prostatic lesions with higher accuracy. Best cut off ADC value with highest diagnostic accuracy and acceptable specificity was 0.92 (x 10^{-3} mm^2/s), also with PSA value >50ng/ml there was 92.30% chances of malignancy.

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