Diagnostic utility of three Tesla diffusion tensor imaging in prostate cancer: correlation with Gleason score values

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Abstract
Background: Preoperative assessment of prostate cancer (PCa) aggressiveness is a prerequisite to provide specific management options. The Gleason score (GS) obtained from prostatic biopsy or surgery is crucial for the evaluation of PCa aggressiveness and personalized treatment planning. Diffusion tensor imaging (DTI) provides valuable information about microstructural properties of prostatic tissue. The most common prostate DTI measures are the fractional anisotropy (FA) and median diffusivity (MD) can give more information regarding the biophysical characteristics of prostate tissue. We aimed to explore the correlation of these DTI parameters with GS levels in PCa patients that can affect the management protocol of PCa.

Results: The computed area under curve (AUC) of the FA values used to differentiate cancer patients from control group was (0.90) with cutoff point to differentiate both groups were ≥ 0.245. The computed sensitivity, specificity, positive and negative predictive values were (84%, 80%, 95.5%, and 50%), respectively, with accuracy 83.3%. FA showed high positive correlation with Gleason score (p value < 0.001). Median diffusivity (MD) showed negative correlation with GS with statistically significant results (p value = 0.013). PCa fiber bundles were dense, orderly arranged, without interruption in the low grade, and slightly disorganized in the intermediate group. However, in the high-grade group, the fiber bundles were interrupted, irregularly arranged, and absent at the site of cancerous foci.

Conclusions: Combined quantitative parameter values (FA and MD values) and parametric diagrams (FA and DTI maps) can be utilized to evaluate prostate cancer aggressiveness and prognosis, helping in the improvement of the management protocol of PCa patients.

Keywords: Fractional anisotropy, Mean diffusivity, Prostate cancer, Diffusion tensor imaging, Gleason score

Background
According to the Global Cancer Statistics 2020, prostate cancer (PCa) is the 2nd non-cutaneous leading cause of cancer death in men, and the 4th most commonly diagnosed cancer [1]. Although different diagnostic tools are prevalent for diagnosis of males suspected to have prostatic cancer, as serum prostate-specific antigen (PSA) levels, transrectal ultrasound (TRUS), and digital rectal examination, the sensitivity and specificity of all these modalities in the early diagnosis of PCa are limited [2].

Generally, the perfect imaging tool in the prostate cancer diagnosis is MRI, because of its great spatial resolution and the outstanding contrast of soft tissue. On the other hand, its routine sequences show moderate specificity and sensitivity for the prostate cancer diagnosis [3, 4].

Diffusion tensor imaging (DTI) is a diffusion weighted image (DWI) extension where the diffusion of water directional dependence can be examined in at least 6
directions [5]. This technique is a tensor and gives extra-
structural data about the anisotropy and magnitude of
diffusion of water in tissues [6, 7].

The prostate contains histologically dissimilar struc-
tures. This leads to diffusion anisotropy, because the
restriction of diffusion is dissimilar in different directions
[8]. DTI can be helpful in providing more information
concerning the prostate biophysical characteristics [6].
It can give both values of fractional anisotropy (FA) and
mean diffusivity (MD) that may reveal the physiologic
and pathologic alterations [9, 10].

Prostate cancer diagnosis is supposed if the levels of
PSA are increased more than 4 ng/ML [11]. The diagnos-
tic work-up of patients with an elevated PSA level and
an increased risk of PCa is continuously changing. His-
topathologic verification via a systematic TRUS-guided
biopsy is the standard clinical procedure to confirm the
diagnosis of PCa [12].

Gleason score (GS) analysis was utilized to assess the
grade of tumor and the patient’s prognosis who suf-
fer from prostate cancer utilizing samples from a biopsy
from the prostate [13]. The total score was established
on the microscopic picture of cells. Half of the score is
established on the commonest cell morphology appear-
ance (scored 1–5) and the other half is established on the
2nd commonest cell morphology appearance (scored 1–5)
[14].

Clinically significant PCa is defined on pathology/his-
tology as Gleason ≥ 7 (including 3+4 with prominent
but not predominant Gleason 4 component), and/or vol-
ume ≥ 0.5 cc and/or have extra prostatic extension [15,
16].

The correlation between functional parameters as
assessed by DTI and the aggressiveness of prostate can-
cer determined by Gleason score (GS) may add a value
in the prediction of prostate cancer pathological grad-
ing and distinguish clinically significant prostate cancer
from indolent prostate cancer noninvasively to enhance
the choice of a proper management and evaluation of the
prognosis of the patient [3, 6].

The objective of this prospective study was to investi-
gate the correlation between diffusion tensor imaging
parameters with Gleason score values in PCa patients
that can affect the management protocol of PCa.

Methods
Institutional review board was obtained for this prospec-
tive study done from July 2020 to March 2022. Informed
consents were obtained from all patients and controls
before MRI examination was done. The study was con-
ducted on 83 consecutive male cases. Their ages ranged
from (35–86 years) and their mean age was about (67 ± 7)
years old.

Inclusion criteria
The study included patients who were clinically sus-
pected to have prostate cancer by digital rectal examina-
tion or by high serum PSA level (> 4 ng/ML). Patients
did not undergo previous hormonal, radio-therapeutic
management, or chemotherapy prior to the MRI studies.
No biopsies were taken in all patients prior to the MRI
examinations.

Exclusion criteria
Patients with general contraindications to do MRI as
patients with cardiac pacemaker, cochlear implant,
patients with motion artifact that leads to poor MR
images quality, patients with prior hormonal, surgical, or
irradiation therapies for prostate cancer. Pathologically
proven lesions other than prostatic adenocarcinoma like
prostatitis or BPH are excluded.

Thirteen patients were excluded from the study. One
patient was claustrophobic and did not complete the
study. Two patients showed images with motion artifacts,
eight patients with multiple benign prostatic hyperplasia
(BPH) nodules at the transitional zone and two patients
with prostatitis.

Patient group (N=50) with clinically suspected pro-
static lesions their mean age (67 ± 7) years old and 20
healthy volunteers their mean age (66 ± 8) years old
which were defined as control group, they were coming
for MRI examinations due to other causes rather than
prostatic disease. Patients were referred from the outpa-
tient clinic of Urology and Nephrology Center, Mansoura
University. Only patients with final histopathological
diagnosis after biopsy were included. Ethics Commit-
tee of the faculty of medicine, University of Mansoura
approved the study protocol.

Image acquisition
Routine MRI together with DTI was carried out for
patients and control groups using a 3-T MRI scanner
(Ingenia, Philips medical systems, Veenpluis, Nether-
lands), imaging in the supine position using phased-array
body coil. The field of view (FOV) was taken from the
iliac crest to the end of symphysis pubis. The bladder,
prostate, and the surrounding structures were included
and well delineated. The following sequences were done,
Axial T1WI: to exclude presence of any hemorrhagic
foci. FOV=200 mm. TR (repetition time)=400 ms.
TE (echo time)=9 ms. Slice thickness=3 mm. Slice
interval=0.3 mm. T2WI, in axial, coronal, and sagit-
tal planes: the gold standard sequence to demonstrate
prostatic anatomy FOV = 200 mm. TR = 5000 ms. TE = 110 ms. Slice thickness = 3 mm. No interslice gap, and matrix: 288 \times 192. DWI: to evaluate any abnormally restricted diffusion seen within the prostate: TE = 85 ms. TR = 7255 ms. FOV = 200 mm. Slice thickness 3 mm. Two b values were used (zero and 1400 s/mm\(^2\)). DTI: using single-shot echo planner-imaging sequences. Matrix: 152 \times 152. TR = 10,000 ms. TE = 100 ms. Number of averages: 1. Slice thickness = 4 mm. No gap. FOV = 260 \times 260 mm\(^2\). Two b values were used: (0 and 1400 s/mm\(^2\)). Acquisition time = 6 min. NSA = three. Flip angle = 90º. Number of directions = 32.

**Image interpretation**
MR images were analyzed by 2 radiologists (YA and RA) with 5- and 15-year experience in uro-radiology and agreed by consensus. They were blinded to the histopathological results. Qualitative analysis was done to the prostate gland to detect the lesions of abnormal low signal intensity (SI) on T2 and restricted signals on DWI, also to detect the integrity of the capsule of the prostate and the extension of the tumors to the adjacent structures as well as the periprostatic fat planes.

**Post-processing**
Following image acquisition, all images were stored in DICOM format, then transferred to a digital workstation (Intellispace portal Workspace 6.0.1 Philips medical systems Netherlands B.V) supplied by the vendor, for processing. Metrics were measured within the detected lesions using region of interest (ROI) method. ROI placement corresponds to the most restricted area in diffusion weighted image, excluding areas of calcification and hemorrhage. (Median ROI area, 0.81cm\(^2\), range, 0.4–2 cm\(^2\)). Each ROI was scanned three times, and the average value was used as the final FA and MD value. FA and MD values were registered in excel sheet. Parametric diagrams (FA and DTI maps) were obtained.

| Table 1 | Validity of MD & FA in discriminating patients with prostate cancer from the control group |
|---------|------------------------------------------------------------------------------------------|
|         | AUC (95% CI) | \(p\) value | Cut off point | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | Accuracy (%) |
| MD      | 0.95 (0.98–1.0) | <0.001* | ≤1.075 | 88.0 | 90.0 | 97.8 | 60 | 88.3 |
| FA      | 0.90 (0.769–1.0) | <0.001* | ≥0.245 | 84.0 | 80.0 | 95.5 | 50.0 | 83.3 |

AUC: area under curve. PPV: positive predictive value. NPV: negative predictive value. *Statistically significant

Fig. 1 a ROC curve for MD in discriminating cases from control groups. b ROC curve for FA in discriminating cases from control groups
After MRI examinations, standard 12-core random systematic TRUS-guided needle biopsy was done for all patient group (50). Histopathological biopsy results were the reference standard. The average estimated duration between the MRI study and the biopsy did not exceed 7 days. TRUS-guided needle biopsy was done, using (Flex focus 500, bk medical, Herlev, Denmark) with high-frequency transrectal transducer (5–9 MHz) and a condom cover. The patient lied in a modified lithotomy position. Anorectal application of a lubricant gel with lidocaine cream was used topically, before insertion of the probe.

**Table 2** Correlation between Gleason score, PSA level and imaging data FA, MD

|            | FA     | PSA level |
|------------|--------|-----------|
| **FA**     | R      | 0.744*    |
|            | P      | <0.001    |
| **MD*10^-3** | R  | −0.347*   |
|            | P     | 0.013     |

*r: Spearman correlation coefficient *Statistically significant

**Final diagnosis**

Axial scans were used to detect any abnormal lesions at the prostate gland, as well as the seminal vesicles infiltration by the tumors. Then, the twelve cores were taken, and tissue biopsies were sent for histopathologic assessment. When TRUS-guided biopsy was done, and the diagnosis of prostatic carcinoma was confirmed, correlation between the values of DTI parameters (FA and MD), PSA level, pathological results, Gleason score, and final diagnoses of the cases were done.

**Statistical analysis and data interpretation**

The data were collected, processed, coded, and introduced to the computer to undergo analysis utilizing SPSS program for windows version 22.0. Armonk, NY: IBM Corp. The qualitative results were expressed utilizing percent and number. The DWI map was obtained following scanning. The quantitative results were expressed utilizing median (minimum and maximum) for nonparametric data, and on the other hand, continuous variables were provided as mean±SD (standard deviation) for parametric data. Receiver operating characteristic (ROC)
curve was used to calculate FA & MD cutoff values with their sensitivity and specificity.

Overall diagnostic accuracy was assessed in terms of the multiclass analysis of the area under the ROC curve (AUC). The level of significance of the collected data was determined as the \( p \) value \( \leq 0.05 \). One-way ANOVA test was utilized to make comparison between Gleason score and DTI metrics (FA, MD). The Spearman’s correlation test was used to determine the strength of the relationships between Gleason score, PSA level and imaging data FA, MD.

**Results**

**Patient demographics**

This research included 50 male patients; the highest prevalence of prostate cancer among this study population was between 70 and 79 years old. All were clinically suspected of prostate cancer. The PSA level for them ranged from 6 to 131 ng/dl (mean ± SD = 35 ± 34 ng/dl), with median value about 20.95 ng/ml. The main level at presentation time was less than 30 ng/ml.

Out of the 50 patients subjected to this study, 23 patients (46%) had obstructive irritative lower urinary tract symptoms, 12 patients (24%) incidentally discovered high PSA, 8 patients (16%) had hematuria, 4 patients (8%) had indwelling of urethral catheter, 2 patients (4%) had bone aches, and 1 patient (2%) had perianal pain.

According to the tumor location, out of the pathologically proven 50 malignant lesions, 12 lesions were located at the right mid prostate, 16 lesions were located at the left mid prostate, 2 lesions were located at the right prostate apex, 6 lesions were located at the left prostate apex, 3 lesions were located at the right prostate base, 6 lesions were located at the left prostate base, and 5 lesions were simultaneously involving the peripheral and central gland regions.

**Histopathological grading:** Among the 50 cases of PCa, 11 cases presented with Gleason scores of \((3+3=6)\), which is considered as a low-grade tumor, 24 cases presented with a Gleason score of \(7\); 11 of score \((3+4=7)\) and 13 of \((4+3=7)\), which is considered as an intermediate grade tumor, 12 cases had Gleason scores of \((4+4=8)\); and 3 cases had Gleason score \((5+4=9)\). Both 8 and 9 groups (15 cases) were considered as a high-grade tumor.

![Fig. 3](scatter_plot.png)
Fig. 4 One-way ANOVA test: FA, MD in correlation with Gleason score among studied patients. FA: fractional anisotropy, MD: median diffusivity

**Table 3** Mean DTI metrics values distribution according to Gleason score

| Gleason score | No | Mean   | SD   | Minimum | Maximum | Test of significance |
|---------------|----|--------|------|---------|---------|---------------------|
| **FA**        |    |        |      |         |         |                     |
| 6             | 11 | .28800 | .073185 | .238 | .500 | $F = 15.14$ $p < 0.001^*$ |
| 7             | 24 | .30342 | .028255 | .250 | .400 |                     |
| 8             | 12 | .39683 | .052066 | .330 | .490 |                     |
| 9             | 3  | .39333 | .011547 | .380 | .490 |                     |
| Total         | 50 | .32784 | .064652 | .238 | .500 |                     |
| **MD**        |    |        |      |         |         |                     |
| 6             | 11 | .8673  | .22055 | .34 | .30 | $F = 2.91$ $p = 0.045^*$ |
| 7             | 24 | .7304  | .14992 | .15 | .20 |                     |
| 8             | 12 | .7016  | .17153 | .40 | .07 |                     |
| 9             | 3  | .6000  | .10000 | .50 | .70 |                     |
| Total         | 50 | .7458  | .18083 | .40 | 1.30 |                     |

*Statistically significant

(See figure on next page.)

**Fig. 5** A 67-year-old male patient, presented with irritative and obstructive lower urinary tract symptoms, his PSA level was 9.8 ng/ml. 

- **a** T2 WI high-resolution pelvic MRI: a well-defined lesion (2 × 1.4 cm) at the right PZ at the level of mid gland with an abnormal hypointense T2WI SI.
- **b** DWI image showed restricted diffusion.
- **c** ROI on DTI image: (FA = 0.26), (MD = 0.85 × 10mm²/sec), **d** DTT map displays dense, orderly arranged fiber bundles without interruption that corresponds with low-grade prostate cancer.
- **e** Transrectal US and biopsy were done: an ill-defined suspicious hypoechochogenic focal lesion at the right PZ (red arrow).
- **f** Histopathological biopsy: prostatic adenocarcinoma, moderately differentiated, combined Gleason score: (3 + 3 = 6). T2WI, T2-weighted imaging; FA, fractional anisotropy; DWI, diffusion-weighted imaging; DTT, diffusion tensor tractography. PZ, peripheral zone
Fig. 5 (See legend on previous page.)
**MRI examination**

**Diffusion tensor imaging metrics**

There was a significant decrease in MD values in the cancerous foci in patients versus normal prostatic foci in controls ($p<0.001$). The measured MD values for the control and patient groups, respectively, were $(1.69 \pm 0.183) \times 10^{-3} \text{mm}^2/\text{sec}$, and $(0.745 \pm 0.180) \times 10^{-3} \text{mm}^2/\text{sec}$, respectively. At ROC curve, the AUC of the MD values used to differentiate, patients from controls were (0.95) with cutoff point to differentiate, both groups were $(\leq 1.075 \times 10^{-3} \text{mm}^2/\text{sec})$. The sensitivity, specificity, positive and negative predictive values were (88%, 90%, 97.8%, and 60%) with accuracy 88.3% (Table 1, Fig. 1a). There was a significant increase in FA values in the cancerous foci in patients versus normal prostatic foci in controls ($p<0.001$). The measured mean FA values for the control and patient groups, respectively, were $(0.219 \pm 0.028)$ and $(0.327 \pm 0.06)$, respectively. At ROC curve, the AUC of the FA values used to differentiate patients from controls were $(0.90)$ with cutoff point to differentiate both groups were $\geq 0.245$. The computed sensitivity, specificity, positive and negative predictive values were (84%, 80%, 95.5%, and 50%), respectively, with accuracy 83.3% (Table 1, Fig. 1b).

When considering the correlation between Gleason score, PSA and imaging data FA, MD: The FA showed high positive correlation with Gleason score (P value $< 0.001$) statistically significant; however, the FA showed a very low positive correlation with PSA (P value = 0.1): statically insignificant. The MD showed a negative correlation with Glasson score and PSA with statistically significant results (Table 2). Scatter plot diagram is used to mathematically show the relationship between the MD and PSA & Gleason score among the 50 studied cases (Figs. 2, 3).

Considering the mean DTI metrics values distribution (FA, MD) according to Gleason score utilizing one-way ANOVA test (Fig. 4): In the 11 patients of Gleason score $(3+3=6)$, the mean FA value was $(0.28 \pm 0.07)$ and the mean MD value was $(0.86 \pm 0.22 \times 10^{-3} \text{mm}^2/\text{sec})$. In 24 patients of Gleason score 7, the mean FA value was $(0.3 \pm 0.02)$ and the mean MD value was $(0.73 \pm 0.14 \times 10^{-3} \text{mm}^2/\text{sec})$. In 12 patients of Gleason score 8, the mean FA value was $(0.39 \pm 0.05)$ and mean MD value was $(0.70 \pm 0.17 \times 10^{-3} \text{mm}^2/\text{sec})$. In 3 patients of Gleason score 9, the mean FA value was $(0.39 \pm 0.01)$ and the mean MD value was $(0.6 \pm 0.1 \times 10^{-3} \text{mm}^2/\text{sec})$ (Table 3).

According to the DTT maps, the PCa fiber bundles were dense, orderly arranged without interruption in the low-grade, slightly disorganized in the intermediate group. However, in the 15 cases of the high-grade group, the fiber bundles were interrupted, irregularly arranged, and absent at the site of cancerous foci.

**Discussion**

The most significant finding in this study is that the measured DTI anisotropy parameter (FA) and diffusivity parameter (MD) had higher sensitivity and diagnostic accuracy in evaluation of the aggressiveness of prostate cancer in correlation with Gleason score, pathological scoring system, and PSA levels.

This study was carried out on 50 patients. The highest prevalence of prostate cancer among this study population was between (70 and 79 years old); this copes with the recorded age incidence of prostate cancer [8, 17]. Clinically speaking, age is considered a significant non-modifiable risk factor for PCa [18, 19]. Some risk factors of PCa can be affected by aging, such as immunity, cholesterol metabolism, obesity, free testosterone levels, and genetic effects [20].

In prostate cancer, FA and MD vary because of altered diffusivity and disorganization of the fibers. (MD) has been used to describe the strength of diffusion in biological tissues which is valid only for homogeneous fluid with free diffusion, diffusion can be hindered or restricted, and result in decreased MD [21].

Fractional anisotropy defines the degree of anisotropy and reflects the degree of alignment of cellular structures and measures the total magnitude of water directional movement along the fibers [22]. In this study, to be more accurate in determination of the FA and MD, especially in large heterogenous lesions, we used the ROI in the portion of the tumor showing the highest SI.
on DWI and the lowest SI on ADC map, compared with the signal from the adjacent tumoral tissue. [23]. We used the ellipse ROI, as it was suggested to be a simpler and appropriate method for MD measurement in PCa [24].

In this study, the mean FA detected among the control group (N = 20) was (0.219 ± 0.028); however, the mean FA among the patient group (N = 50) was (0.327 ± 0.065) with the cutoff point of FA value among the 70 male included in this study was (≥ 0.245) above which the detected lesion is considered a cancer lesion with 84% sensitivity and 80% specificity.

The mean MD value was detected among control group (N = 20) (1.69 ± 0.183 × 10^{-3} mm²/sec); however, MD value detected among the patient group (N = 50) was (0.745 ± 0.180 × 10^{-3} mm²/sec). The cutoff point of MD value among the 70 males included at this study was (≤ 1.075) below which the detected lesion is considered a cancer.

The greater FA values of cancer lesions than FA values of normal tissues as well as the lesser mean cancerous tissue MD values than the normal values coincide with Onya A., et al. who reported on 2017 that FA of cancerous tissue is higher than of normal tissues [22]. This also agreed with Li L., et al. who concluded on 2015 that elevated FA values and reduced MD values in prostate cancer at 3 T MRI machine [3].

Gholizadeh N., et al. also on 2019 showed reduced diffusivity (MD) and elevated fractional anisotropy (FA) values of cancer foci from several DTI maps suggesting increased cellularity or overcrowded cancerous tissues [6]. This can be explained as the increased intracellular viscosity and the number of cell membranes in cancerous tissues leads to diffusion directionality and restricted diffusion, whereas water diffusion in benign tissue is fairly isotropic with low FA and high MD [25].

This is partially contradicted to the results by Manenti G., et al. on 2007 who detected significant reduction in MD and FA measurements in PS prostate cancer compared to healthy areas [26]. He related the decreased FA value to the nature of tumorous tissues, which were described as areas of absent or reduced fibers. This can be explained by a shift of the adjacent healthy tissues “fibers.” FA values were reduced in the tumor area, contrary to the surrounding healthy tissue, because of the disorganized structure of the tumor itself (tumoral necrosis or degeneration) [26].

High-grade tumors having high cellularity with packed cells this will have elevated levels of FA; on the other hand, tumors of low grade showing decreased cellularity with cells that are randomly arranged will have decreased FA [3, 7]. Diffusion is more restricted and hindered in the cases of poorly formed/fused/crribiform glands that significantly reduce MD values in high-grade tumors [27].

PSA level showed decreased specificity in prostate cancer diagnosis, because of its false positive results in benign diseases as prostatitis and BPH; consequently, increased PSA does not essentially demonstrate the presence of PCa [11]. Moreover, its normal level does not rule out the presence of PCa. On the other hand, evaluation of PSA is still utilized because of absence effective biomarkers in detection of PCa [28, 29]. This coincides with our results as PSA showed a statically insignificant very low positive correlation with FA, and a statistically significant negative correlation with MD.

In this study, we found that the FA showed high positive correlation with Gleason score (p value < 0.001) which is statically significant. Furthermore, we found that MD showed negative correlation with Glasson score with statistically significant results (p value = 0.013). These alterations may be because of the progressively dense arrangement of cells in the tumors of high grades; additionally, the extracellular space decreases [17]. This coincides with Tian W, et al. [17] who found nearly the same results.

This is not consistent with Wang S, et al. who reported a negative correlation between the values of FA and Gleason scores, signifying that an elevation in Gleason scores will lead to a slowly decrease in the value of FA [25]. Nezzo M, et al. documented no correlation between the value of FA and Gleason score. This conflict in FA correlation with prostate cancerous tissues may be related to the difference in the parameters of acquisition protocols and/or post-processing techniques [27].

The limitations of this study could be summarized in the small number of patients enrolled in the study, together with absence of follow-up DTI for the patients. No fusion or cognitive biopsy on the suspected lesion was observed. Another limitation of this study was carried
Fig. 7 (See legend on previous page.)
out in a single-center study, on one type of MRI scanner. It is very well known that diffusion imaging, including DTI, is very dependent on the scanner type as well as the imaging protocol and modeling.

In conclusion
The results of this research showed that there was a significant correlation between MD and FA values, obtained from DTI and the GS in PCa. So, combined quantitative parameter values (FA and MD values) and parametric diagrams (FA and DTI maps) can be utilized to evaluate prostate cancer aggressiveness, and prognosis, helping in the improvement of the management protocol.

Abbreviations
PCa: Prostate cancer; GS: Gleason score; DTI: Diffusion tensor imaging; FA: Fractional anisotropy; MD: Mean diffusivity; AUC: Area under curve; PSA: Prostate-specific antigen; TRUS: Transrectal ultrasound; DWI: Diffusion weighted imaging; BPH: Benign prostatic hyperplasia; SI: Signal intensity; ROI: Region of interest; SD: Standard deviation; ROC: Receiver operating characteristic; PPV: Positive predictive value; NPV: Negative predictive value; BPH: Benign prostatic hyperplasia.

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Author contributions
RA, YA, and ST are responsible as the guarantor of integrity of the entire study. Study concept and design were performed by RA and ST. RA and YA were involved in clinical studies. RA and YA helped in experimental studies/data analysis. RA and YA contributed to statistical analysis. Manuscript preparation was performed by RA and ST. RA and ST helped in manuscript editing. All authors read and approved the final manuscript.

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Availability of data and materials
Due to privacy regulations, the clinical data collected in this study are not deposited in a public registry, but the data can be made available via a request to the corresponding author.

Declarations
Ethics approval and consent to participate:
The Institutional research board of Faculty of medicine, University of Mansoura, approved the study (Proposal code: MS.19.07.735). A written consent was obtained from the study participants to participate. It was approved by the ethics committee.

Consent for publication
A written consent to publish this information was obtained from study participants.

Competing interests
The authors declare that they have no competing interests, and no relationships with any companies, whose products or services may be related to the subject matter of the article.

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