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ABDOMINAL IMAGING

ORIGINAL ARTICLE

Evaluation of prostate volume in mpMRI: comparison of the recommendations of PI-RADS v2 and PI-RADS v2.1

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PURPOSE
We aimed to evaluate the prostate volumes calculated as recommended in the PI-RADS v2 and PI-RADS v2.1 guidelines, intraobserver and interobserver variability, and the agreement between the two measurement methods.

METHODS
Prostate mpMRI examinations of 114 patients were evaluated retrospectively. T2-weighted sequences in the axial and sagittal planes were used for the measurement of the prostate volume. The measurements were performed by two independent observers as recommended in the PI-RADS v2 and PI-RADS v2.1 guidelines. Both observers conducted the measurements twice and the average values were obtained. In order to prevent bias, the observers carried out measurements at one-week intervals. In order to assess intraobserver variability, observers repeated the measurements again at one-week intervals. The prostate volume was calculated using the ellipsoid formula (W×H×L×0.52).

RESULTS
Intraclass correlation coefficient (ICC) revealed almost perfect agreement between the first and second observers for the measurements according to both PI-RADS v2 (0.93) and PI-RADS v2.1 (0.96) guidelines. The measurements were repeated by both observers. According to the ICC values, there was excellent agreement between the first and second measurements with respect to both PI-RADS v2 and PI-RADS v2.1 for first (0.94 and 0.96, respectively) and second observer (0.94 and 0.97, respectively). For both observers, the differences had a random, homogeneous distribution, and there was no clear relationship between the differences and mean values.

CONCLUSION
The ellipsoid formula is a reliable method for rapid assessment of prostate volume, with excellent intra- and interobserver agreement and no need for expert training. For the height measurement, the recommendations of the PIRADS v2.1 guideline seem to provide more consistently reproducible results.

The prostate gland is one of the organs for which the disease incidence and prevalence in men increases with age. Prostate volume (PV) has an important role in the evaluation and management of both malignant and benign prostate diseases (1–3). In benign prostatic hyperplasia (BPH), prostate volume is used to decide upon treatment and evaluate response to medical therapy (3–5). In the diagnosis of prostate cancer, one of the important markers is prostate-specific antigen (PSA), but it has low specificity, and therefore PSA derivatives are used to increase its specificity. One example is PSA density, which is obtained by dividing the PSA value by PV. In the treatment of prostate cancer, PV is important, and the effectiveness of brachytherapy decreases in prostates with a volume greater than 50 mL (6). Furthermore, PV is used to identify appropriate patients for brachytherapy and select the number of radioactive seeds, and also determine fractionation for external beam radiation, radical prostatectomy operating planning and continence rate counseling, and focal therapy candidacy preparation (7, 8). For these reasons, it is vital to accurately calculate PV.

There are many methods that can be used to calculate PV, with the ellipsoid formula being one of the most preferred since it is easy to apply and highly time-efficient (1–4, 9). Many studies have shown that this method has high accuracy due to the elliptic shape of

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the prostate (1, 2, 10–13). The ellipsoid formula is obtained by multiplying the height (anterior-posterior), width (medio-lateral) and length (cranio-caudal) values of the prostate by 0.52. These measurements can be performed by transrectal ultrasonography (TRUS) or magnetic resonance imaging (MRI). TRUS has certain disadvantages, such as being operator-dependent and susceptible to sonographic artifacts (14). MRI, which has become increasingly popular in recent years, allows for an accurate definition of the prostate boundaries and multiplanar measurements through its high contrast resolution of soft tissues (1, 5). It also provides more accurate measurements than TRUS (4, 15, 16).

In order to ensure global standardization in the reporting of prostate MRI findings, PI-RADS v2 published in 2015, which is the revised version of PI-RADS 1.0, and the last updated version PI-RADS v2.1 made available in 2019, propose different calculation methods for the measurement of height in obtaining PV (17, 18). The midaxial plane is recommended for this measurement in PI-RADS v2, while the midsagittal plane is recommended in PI-RADS v2.1. This study aimed to evaluate the interobserver and intraobserver variability of PV calculated by both measurement methods and the agreement between the two measurement methods.

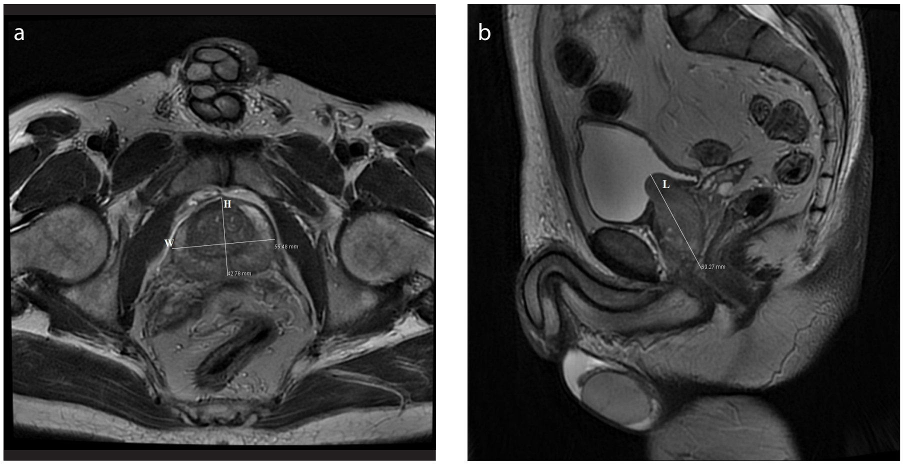

Figure 1. a, b. Method according to PI-RADS v2: maximum height and width measurements in T2-weighted images in the midaxial plane **(a)**, and length measurement in T2-weighted images in the midsagittal plane **(b)**.

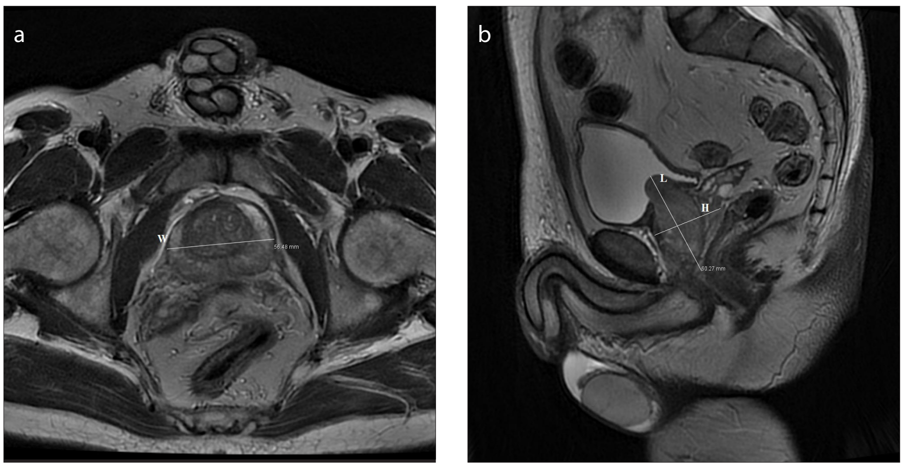

Figure 2. a, b. Method according to PI-RADS v2.1: maximum width measurement in T2-weighted images in the midaxial plane **(a)**, and maximum height and length measurements in T2-weighted images in the midsagittal plane **(b)**.

Methods

The study was approved by the Ethics Committee of the Faculty of Medicine of Eskişehir Osmangazi University (No: 25403353-050.99-E.145728 Date: 18.12.2019). The study was conducted in accordance with the principles of the Helsinki Declaration. All image data used in this study were obtained from routine imaging at our institution. Datasets were evaluated retrospectively. Therefore, approval and informed consent were not necessary and were waived by our local institutional review board. The MRI images of patients who underwent prostate mpMRI imaging between June 2016 and June 2019 were evaluated retrospectively. Patients who had undergone prostate surgery or radiotherapy before the MRI were excluded from the study. The MRI scans of the remaining 114 patients were included in the study.

All mpMRI scans were performed on a 3 T (General Electric) MRI device using a 48-channel body coil. T2-weighted sequences in the axial and sagittal planes were used for the measurement of PV. Fast spin-echo sequence was used for T2-weighted images, and the imaging parameters were as follows: TR/TE, 8300/110; slice thickness, 3 mm; and field of view, 20 cm. The measurements were performed by two independent observers (observer 1, 12 years of experience; observer 2, 4 years of experience) who both performed two measurements for each parameter from which the average values were obtained. In order to prevent bias, the observers performed the measurements according to the PI-RADS v2 and PI-RADS v2.1 guidelines at one-week intervals. To assess intraobserver variability, both observers repeated the measurements again at one-week intervals. For the PI-RADS v2 measurements, the length in the midsagittal plane and height and width in the midaxial plane were measured (Fig. 1). According to PI-RADS v2.1, the length and height in the midsagittal plane and width in the midaxial plane were measured (Fig. 2). PV was calculated using the ellipsoid formula (W×H×L×0.52).

Main points

- Since prostate volume (PV) plays an important role in the management of both benign and malignant diseases, it should be included in prostate mpMRI reports.
- The ellipsoid formula is a fast and reliable method for calculating PV.
- The midsagittal plane recommended by PI-RADS v2.1 for the height measurement on prostate MRI seems to be more consistently reproducible.

Table 1. Descriptive statistics of prostate volume

	Minimum	Maximum	Mean	SD
Observer 1 (PI-RADS v2) First measurement	15.39	190.79	63.24	30.52
Observer 1 (PI-RADS v2.1) First measurement	18.06	195.24	59.80	29.02
Observer 1 (PI-RADS v2) Second measurement	18.76	194.69	65.32	28.34
Observer 1 (PI-RADS v2.1) Second measurement	17.68	187.45	61.24	28.79
Observer 2 (PI-RADS v2) First measurement	20.80	181.70	60.14	27.40
Observer 2 (PI-RADS v2.1) First measurement	18.77	171.14	60.65	26.18
Observer 2 (PI-RADS v2) Second measurement	16.33	152.47	57.43	25.41
Observer 2 (PI-RADS v2.1) Second measurement	22.46	194.68	59.62	27.39

PI-RADS v2, prostate imaging-reporting and data system version 2; PI-RADS v2.1, prostate imaging-reporting and data system version 2.1; SD, standard deviation.

Table 2. ICC statistics

Method	Agreement	ICC (95% CI)	*p*
PI-RADS v2	Interobserver	0.93 (0.90–0.95)	<0.001
PI-RADS v2.1	Interobserver	0.96 (0.94–0.97)	<0.001
PI-RADS v2 (observer 1)	Intraobserver	0.94 (0.93–0.96)	<0.001
PI-RADS v2.1 (observer 1)	Intraobserver	0.96 (0.95–0.97)	<0.001
PI-RADS v2 (observer 2)	Intraobserver	0.94 (0.92–0.96)	<0.001
PI-RADS v2.1 (observer 2)	Intraobserver	0.97 (0.96–0.98)	<0.001

ICC, intraclass correlation coefficient; CI, confidence interval; PI-RADS v2, prostate imaging-reporting and data system version 2; PI-RADS v2.1, prostate imaging-reporting and data system version 2.1.

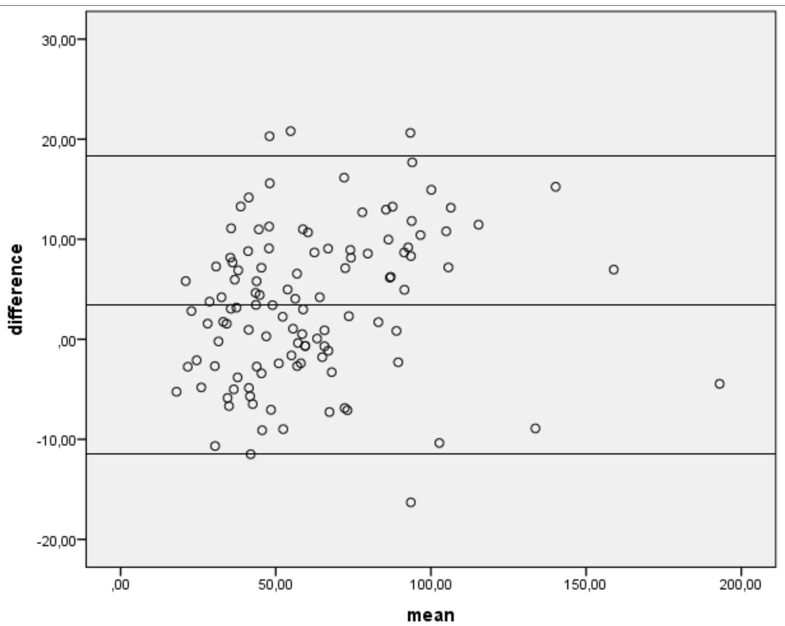

Figure 3. Bland-Altman plot between PI-RADS v2 and PI-RADS v2.1 for the first observer.

Statistical analysis

SPSS software v. 22.0 (IBM Corp.) was used for statistical analysis. Normality analysis was performed by the Shapiro-Wilk test. The mean, standard deviation (SD), minimum and maximum values were obtained as descriptive statistics of continuous data, and frequency (percentage) values for discrete data. The intraclass correlation coefficient (ICC) was used to assess intraobserver and interobserver variability. Based on the 95% confidence interval (CI) of the ICC estimate, values less than 0.5, 0.5 to 0.75, 0.75 to 0.9, and greater than 0.90 indicate poor, moderate, good, and excellent reliability, respectively. The Bland-Altman analysis was used to examine the agreement between the two proposed measurement techniques (PI-RADS v2 and PI-RADS v2.1). Bland-Altman plots, together with mean difference and 95% limits of agreement (LOA), were created to provide a graphical representation.

Results

The age of the 114 patients included in the study ranged from 47 to 78 years (mean±SD, 63.65±7.15 years). The descriptive statistics of PV calculated using the ellipsoid formula and measured by the first and second observers as recommended in PI-RADS v2 and PI-RADS v2.1 are given in Table 1. Measurements performed in accordance with the recommendation of both PI-RADS v2 and PI-RADS v2.1, ICC (95% CI) indicated excellent agreement between the first and second observers ($p < 0.001$). Moreover, excellent intraobserver agreement was found between the first and second measurements and between the two guidelines (PI-RADS v2 and PI-RADS v2.1) based on ICC (95% CI) ($p < 0.001$). The findings are summarized in Table 2.

When the results of Bland-Altman analysis were examined for absolute relational agreement between the PI-RADS v2 and v2.1 methods, it was observed that the differences for both the first observer (Fig. 3) and the second observer (Fig. 4) showed a random, homogeneous distribution, and there was no clear relationship between the differences and mean values.

Discussion

PV is important in the diagnosis and treatment of both benign and malignant prostate diseases. In both PI-RADS v2 and

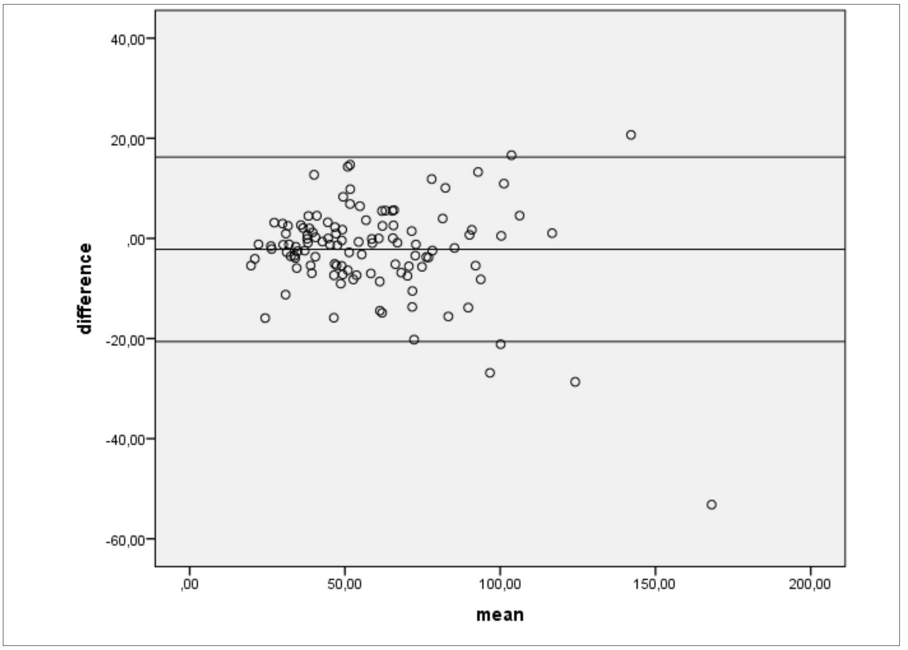

Figure 4. Bland-Altman plot between PI-RADS v2 and PI-RADS v2.1 for the second observer.

2.1, the measurement of PV is strongly recommended for mpMRI reports (17–20). The ellipsoid formula is accepted in both guidelines as the measurement method; however, of the three measurement parameters necessary to measure PV with the ellipsoid formula, the use of different planes is proposed for height measurement in PI-RADS v2 and v2.1 (17, 18). Repeatability is one of the most important parameters that determine the reliability of different measurement methods. To the best of our knowledge, there is no study in the literature evaluating the measurements obtained by both methods in terms of intra- and interobserver agreement. Thus, the current study is the first in the literature in relation to this evaluation.

In this study, interobserver agreement was found to be excellent in both PI-RADS v2 and PI-RADS v2.1. ICC was calculated as 0.96 for PI-RADS v2.1 and 0.93 for PI-RADS v2. Although both values indicated excellent agreement, the degree of agreement was higher for PI-RADS v2.1. In PI-RADS v2.1, it is reported that the purpose of the recommended measurement method is to provide a uniform approach to calculate PV (18). According to the results of our study, PI-RADS v2.1 provides more consistently reproducible results in terms of this uniformity approach due to the higher agreement between the observers. The reason for the higher agreement obtained from PI-RADS v2.1 in our study may be the shape characteristics of the prostate gland. According to the recommendation of PI-RADS v2.1, the height measurement is performed in the midsagittal plane, perpendicular to the sagittal axis of the prostate gland. This axis is not always the same as in the actual sagittal plane, and it is slightly oblique. In PI-RADS v2, the height is measured perpendicular to the width of the axial plane. The fact that the shape of the prostate gland is not completely cylindrical can explain why height measurements in the midsagittal plane provide more accurate results. This hypothesis is supported by the ICC values of this study.

In this study, intraobserver agreement was found to be excellent for both observers although they had different levels of experience in prostate imaging. According to the results of our study, calculating ellipsoid formula of the prostate does not require expert training.

There is no similar study in the literature that evaluates intra- and interobserver agreement based on mpMRI images. However, Jeong et al. (16), who compared prostate TRUS, MRI and 3D planimetric magnetic resonance volumetry results and PV in radical prostatectomy (RP) specimens, reported that the height measurement in the midsagittal plane gave more accurate results. That study was performed using an endorectal coil on a 1.5 T MRI device. Sosna et al. (21) conducted a similar study using a 3 T external-phase array coil and found similar results. The authors reported that the volume information obtained from the height measurement performed from the midsagittal plane provided the most accurate values with respect to the PV measured from the RP specimens. Since the main aim of our study was to evaluate the agreement between PI-RADS v2 and v2.1 and volume standardization cannot be achieved in RP specimens, we did not evaluate this aspect. However, our higher intra- and interobserver agreement in the midsagittal plane measurements suggests that PI-RADS v2.1 provides more consistently reproducible results, which confirms the findings of previous studies.

In their study taking RP specimen measurements as reference and using the ellipsoid formula to calculate PV, Terris et al. (22) concluded that the height measurement in the midaxial plane provided more accurate assessment compared with the value obtained from the midsagittal plane, and the authors attributed this finding to the inability to clearly separate the bladder neck and seminal vesicles from the level of the prostate base. Similarly, in another study conducted with TRUS, more accurate results were found in the height measurements from the midaxial plane (16). However, it is possible to distinguish between prostate and bladder neck and seminal vesicles by MRI in both planes. TRUS and MRI may give different results due to distortion in TRUS. In their study with TRUS, Park et al. (9) similarly reported that PV calculated based on the height measurements in the midaxial plane presented more accurate results in relation to the pathology specimen. Nevertheless, many studies have reported that MRI is more reliable than TRUS (16). Therefore, we consider that the results of MRI included in our study are more reliable and standardized. In addition, previous studies conducted with TRUS did not evaluate intra- and interobserver agreement, and therefore it is not possible to assess the repeatability of their results.

Our study has some limitations. First, the study has a retrospective nature. Second, to determine the actual gland volume, the most appropriate approach may be to perform the measurements in RP specimens. As the gold standard method, taking pathology specimen measurements as reference may have been a more appropriate approach, but this was not possible in the current study because most of our patients had no pathology specimens and for some of those with pathology specimens, we were not able to access PV data, and additionally PV measurement in RP pathology was not standardized. After standardizing volume measurement in RP, further research can provide more accurate results concerning the agreement between the two guidelines in relation to the reference method.

PI-RADS v2 recommends PV measurement using manual or automatic segmentation and the ellipsoid formula. Some studies have shown that these three methods differ from each other and the measurements made from radical prostatectomy specimens. However, some cutoff values are determined according to the volume measurement and they are used in patient management. Therefore, it is important to determine a standard method and imaging technique for PV measurement. There is no consensus on this issue yet. In PI-RADS v2.1, there are recommendations to achieve uniformity in the execution of the ellipsoid formula. The ellipsoid formula is frequently preferred due to its ease of application, requirement of no additional software, time-efficiency, and high interobserver agreement.

In conclusion, PV is one of the parameters that should be included in prostate mpMRI reports. The ellipsoid formula is a reliable method for rapid assessment of prostate volume, with excellent intra- and interobserver agreement. For the height measurement, the recommendations of the PIRADS v2.1 guidelines seem to provide more consistently reproducible results.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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