Original Paper

Is the Ellipsoid Formula Reliable in Prostate MRI?

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ABSTRACT: Our study seeks to study the accuracy of the ellipsoidal formula in prostate MRI of different sizes and to establish the limits of its use. The study included 31 patients with a well-visualized, intact prostatic capsule, excluding malignantly transformed prostates, as well as treated prostates, in which the contrast between the prostatic capsule and parenchyma is reduced. Each patient's prostatic volume was recalculated according to the ellipsoidal formula, and then it was compared with the prostatic volume calculated by the segmentation method. The two calculated volumes were similar, in some cases almost identical, with a slight tendency to underestimate prostate volume below 100cm^3, in total in 18 cases, on average by 7.6% (+/-6%), overestimation of those with a volume over 100cm^3, a total of 13 cases, on average by 3.2% (+/-2.5%), and of all, in 4 cases the difference between the two formulas was below 1%. There was no statistical difference between the two variables, Student's t-test p-value=0.039. With a precision of 92% (+/-6%), the ellipsoidal formula can be considered accurate when it is correctly performed, but if we take into account the importance that PSA density is starting to have in diagnosis, treatment and follow-up, the calculation of a secondary value through the segmentation method or high-precision software can be motivated when the ellipsoidal formula returns a value close to a threshold.

KEYWORDS: *Prostate volume, Ellipsoid formula, MRI.*

Introduction

With the increasing availability of high-quality prostate magnetic resonance imaging (MRI), there is an emerging trend to base clinical decisions on it.

Prostate Imaging-Reporting and Data System (PI-RADS) [1] is the most standardized method of communication between radiologists and urologists that we currently have, classifying the risk of prostate cancer on a scale from 1-very unlikely to 3-equivocal risk and up to 5-very likely.

PI-RADS 3 lesions have proven to be controversial because of the reduced specificity for prostate cancer, and even less for clinically significant cancer [2-4].

On the other hand, since prostatic specific antigen (PSA) is produced by both healthy prostate tissue and prostate cancer, modifying the PSA value by prostate volume may enhance PSA's ability to identify patients who are prostate cancer carriers.

This concept was inspired by the well-known PSA density [5-9], which is calculated by dividing the PSA value by the volume of the prostate.

The most used method of calculating the prostate volume is, due to its shape, the ellipsoidal formula: "volume=4/3×π×A×B×C" adapted and simplified into "0.52×width×depth ×height" [10].

Studies have shown that PSA density with a cut off of 0.1ng/mL/mL appears to be a useful marker that can stratify the risk of clinically significant prostate cancer [7,11-17].

Our study seeks to study the accuracy of the ellipsoidal formula in prostate MRI of different sizes and to establish the limits of its use.

Methods

The study included 31 patients, chosen from our database according to the prostate size described in the examinations performed between January 2020 and August 2023 in the Medical Imaging Department of the University of Medicine and Pharmacy of Craiova using a Philips Ingenia 3.0T MRI scanner.

The age of the patients was ranging from 25 to 82 years.

Only patients with a well-visualized, intact prostatic capsule were included in the study, excluding malignantly transformed prostates, as well as treated prostates, in which the contrast between the prostatic capsule and parenchyma is reduced, as well as those with transurethral resection of the prostate.

The way in which they were selected from the database was based on the initial prostatic volume described in the report, which was between 19.96cm^3 and 256.62cm^3, slightly progressive along the entire interval, so that we obtained 6 examinations with prostate volume under 50cm^3, 9 examinations with prostate volume

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between 50-100cm^3 and 16 examinations with prostate volume over 100cm^3.

Each patient's prostatic volume was recalculated according to the ellipsoidal formula (Figure 1), and then it was compared with the prostatic volume calculated by the segmentation method.

Student's t-test (2-tailed, assuming unequal variance) was used to assess the significance of the difference between the two means.

P-values under 0.05 were considered significant.

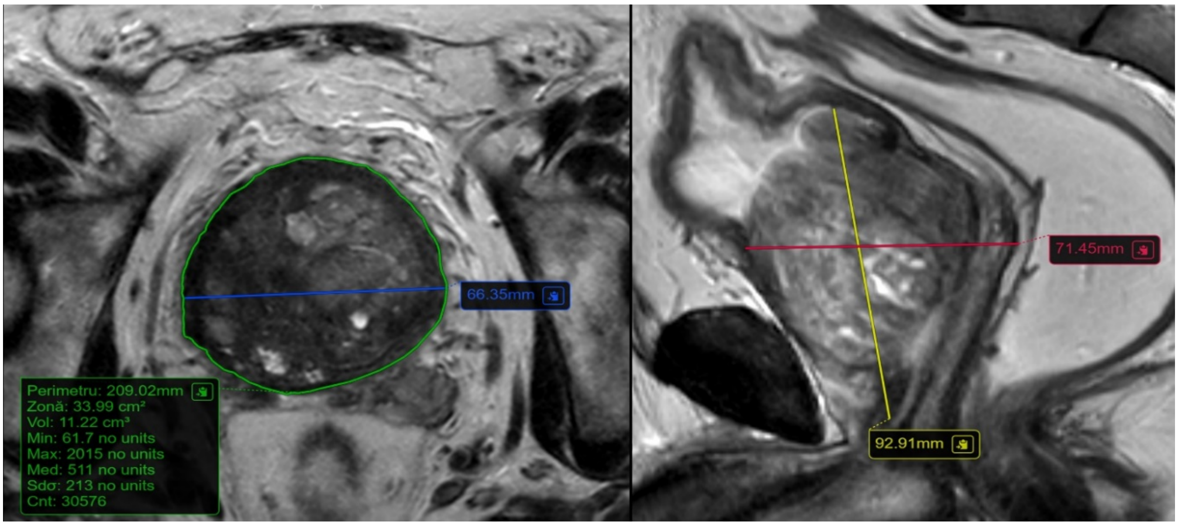

Figure 1. Left: green-segmental volume calculated at the level of the slice, blue-transverse diameter; right: yellow-cranio-caudal diameter, red-antero-posterior diameter.

Given the anatomical obliquity of the gland on the axial plane, there is a potential risk of volume overestimation if the prostate AP dimension is measured on axial imaging.

This is comparable to cutting a shape into larger slices by cutting it diagonally rather than perpendicularly.

Obtaining the anterior-posterior measurement on sagittal imaging is now advised by the most current PI-RADS update (v2.1) in order to reduce the potential risk of the so-called "salami effect" when using the ellipsoid method to calculate volume (Figure 2).

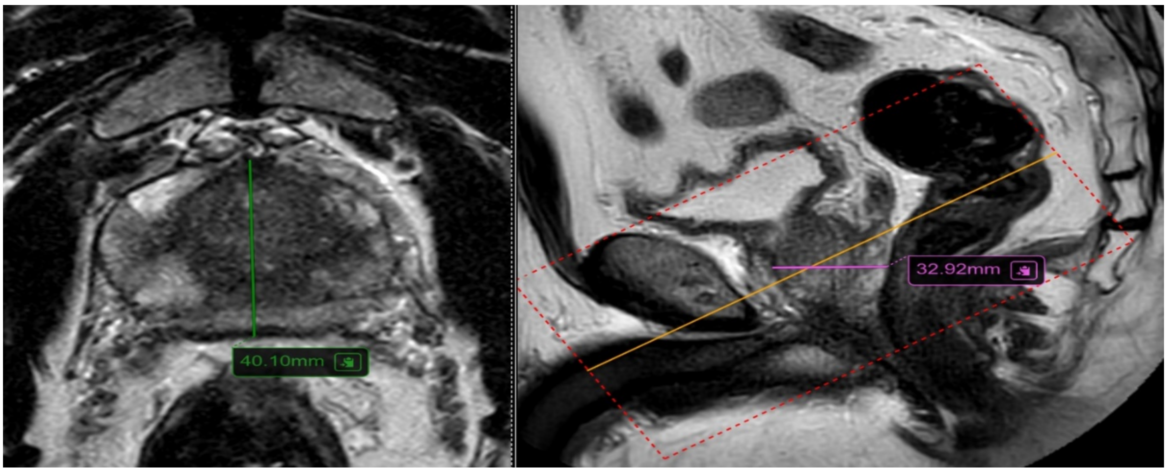

Figure 2. "Salami effect" left: the antero-posterior diameter calculated on the transverse sequence; right: the antero-posterior diameter calculated on the sagittal sequence; the transverse sequence is at the level of the yellow line in the sagittal sequence.

The segmentation method was performed by using the software integrated in the 3Dnet^{TM} platform provided by $^{©}$Biotronics3D, used by two radiologists with at least 3 years of experience in prostate mpMRI examination.

This method consists in the manual segmentation of the prostate from each transverse slice, the area of which is calculated and relative to the thickness of the slice (3mm in the MRI protocol we used) the volume at the level of that slice is obtained, and by adding all from the first slice, on which the apex of the prostate can be seen, to the last, in which its base can be seen.

This method remains accurate no matter what irregularities are present on the surface of the prostate, and that's why we consider it a good benchmark for comparison with the formula used (Figure 1).

The MRI protocol used for the sequence on which the volume of the prostate was calculated by the segmentation method consisted of an oblique axial sequence, positioned perpendicular to the prostatic urethra and parallel to the base of the urinary bladder, with a small field of view of 180 X 230mm, but large enough to cover the entire prostate and the seminal vesicles.

In order for this method to be precise, we used small slice thicknesses of 3mm and a spatial gap equal to these, otherwise there would have been non-visible areas that would have reduced the sensitivity of the method.

The manual segmentation of the prostate at the level of each slice was done following the prostatic capsule, a challenge representing the last apical and basal slice because the edge is not obvious due to its angulation.

In order to keep a correct report, the segmentation at these levels was done with the help of sagittal and coronal sequences.

The resulting volumes were obtained from the precise calculations obtained after the recalculation of the ellipsoidal formula, respectively the addition of the volumes of all slices of each prostate, both using values up to hundredths of a centimeter.

Results

The results of the ellipsoidal formula can be seen in Table 1.

Table 1. T ⌀-transverse diameter, CC ⌀-cranio-caudal diameter, AP ⌀-antero-posterior diameter and the volume returned by the ellipsoidal formula, in ascending order.

T ⌀	CC ⌀	AP ⌀	ELLIPSOIDAL FORMULA
41.59mm	39.50mm	23.37mm	19,96 cm^3
46.05mm	34.25mm	29.89mm	24,51 cm^3
49.34mm	39.35mm	32.92mm	33,23 cm^3
47.14mm	44.21mm	33.35mm	36,14 cm^3
49.75mm	46.65mm	32.64mm	39,39 cm^3
49.80mm	43.63mm	39.31mm	44,41 cm^3
42.94mm	57.85mm	40.66mm	52,52 cm^3
46.97mm	51.12mm	45.82mm	57,20 cm^3
53.46mm	51.48mm	44.18mm	63,22 cm^3
53.95mm	51.58mm	43.92mm	63,55 cm^3
53.02mm	63.43mm	41.24mm	72,12 cm^3
49.55mm	62.02mm	47.17mm	75,37 cm^3
60.31mm	59.90mm	43.69mm	82,07 cm^3
56.19mm	60.88mm	50.30mm	89,47 cm^3
59.99mm	64.33mm	47.36mm	95,04 cm^3
55.72mm	71.82mm	48.75mm	101,44 cm^3
63.85mm	71.66mm	45.01mm	107,09 cm^3
69.60mm	61.72mm	54.92mm	122,67 cm^3
59.64mm	74.19mm	54.24mm	124,79 cm^3
61.03mm	69.63mm	58.73mm	129,77 cm^3
64.69mm	66.50mm	60.67mm	135,71 cm^3
65.22mm	72.75mm	55.36mm	136,58 cm^3
56.42mm	78.89mm	59.47mm	137,64 cm^3
64.42mm	75.15mm	57.24mm	144,09 cm^3
62.61mm	77.88mm	58.84mm	149,19 cm^3
67.61mm	77.97mm	59.91mm	164,22 cm^3
65.59mm	98.22mm	55.80mm	186,92 cm^3
69.23mm	83.84mm	64.97mm	196,09 cm^3
67.45mm	83.06mm	68.33mm	199,06 cm^3
66.35mm	92.91mm	71.45mm	229,03 cm^3
77.35mm	93.10mm	69.33mm	259,61 cm^3

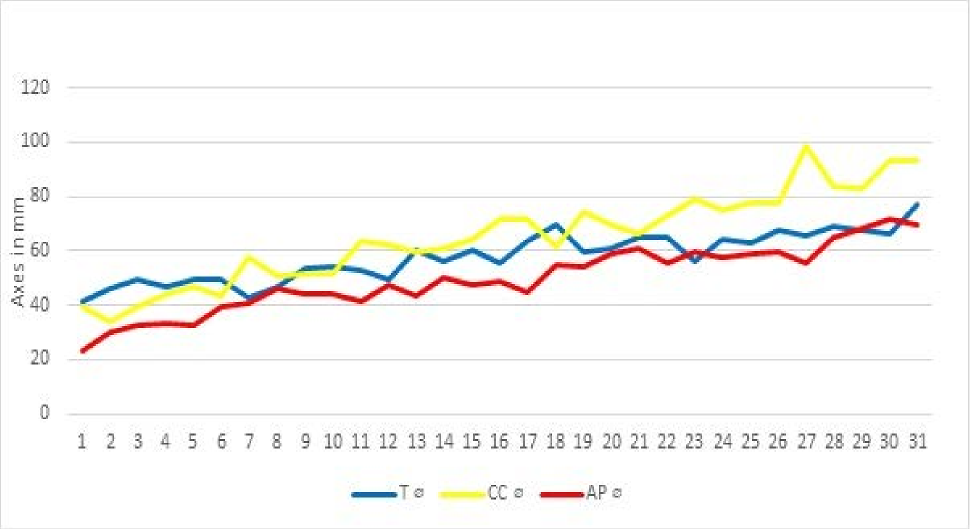

Figure 3. Blue line T ⌀-transverse diameter, yellow line CC ⌀-cranio-caudal diameter, red line AP ⌀-antero-posterior diameter and the proportion in which they change with the increase in volume of the prostate.

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Figure 3 shows us how the ratio of the 3 dimensions of the prostate varies as it grows in size.

There are certainly individual variations, but it can be observed how the transverse dimension tends to change a little, the antero-posterior a little more, and the cranio-caudal changes a lot, especially in the 2nd half of the graph.

The fact that the cranio-caudal size of the prostate varies a lot was also observed in the calculation of the volume by the segmentation method, the number of slices on which the segmentation was made varying from 12 to 33 slices.

The results of the final calculations can be seen in the Table 2, where the prostatic volume calculated by the ellipsoidal formula is compared with the one calculated by the segmentation method.

Table 2. In ascending order, the volume returned by the segmentation method, by the ellipsoidal formula, and the percentage difference between them. Student t test, p=0.039, not significant.

SEGMENTAL METHOD	ELLIPSOIDAL FORMULA	PERCENTAGE DIFFERENCE
24,70 cm^3	19,96 cm^3	-0,191 %
25,52 cm^3	24,51 cm^3	-0,039 %
35,58 cm^3	33,23 cm^3	-0,066 %
36,47 cm^3	36,14 cm^3	-0,009 %
50,27 cm^3	39,39 cm^3	-0,216 %
50,54 cm^3	44,41 cm^3	-0,121 %
51,37 cm^3	52,52 cm^3	0,022 %
63,89 cm^3	57,20 cm^3	-0,104 %
64,26 cm^3	63,22 cm^3	-0,016 %
66,83 cm^3	63,55 cm^3	-0,049 %
76,86 cm^3	72,12 cm^3	-0,061 %
79,54 cm^3	75,37 cm^3	-0,052 %
94,84 cm^3	82,07 cm^3	-0,134 %
102,45 cm^3	89,47 cm^3	-0,126 %
101,67 cm^3	95,04 cm^3	-0,065 %
104,32 cm^3	101,44 cm^3	-0,027 %
109,85 cm^3	107,09 cm^3	-0,025 %
115,96 cm^3	122,67 cm^3	0,057 %
122,46 cm^3	124,79 cm^3	0,019 %
135,73 cm^3	129,77 cm^3	-0,043 %
130,54 cm^3	135,71 cm^3	0,039 %
139,36 cm^3	136,58 cm^3	-0,019 %
135,17 cm^3	137,64 cm^3	0,018 %
143,43 cm^3	144,09 cm^3	0,004 %
143,03 cm^3	149,19 cm^3	0,043 %
163,81 cm^3	164,22 cm^3	0,002 %
180,81 cm^3	186,92 cm^3	0,033 %
195,21 cm^3	196,09 cm^3	0,004 %
190,88 cm^3	199,06 cm^3	0,042 %
209,41 cm^3	229,03 cm^3	0,093 %
250,18 cm^3	259,61 cm^3	0,037 %

The two calculated volumes were similar, in some cases almost identical, with a slight tendency to underestimate prostate volume below 100cm^3, in total in 18 cases, on average by 7.6% (+/-6%), overestimation of those with a volume over 100cm^3, a total of 13 cases, on average by 3.2% (+/-2.5%), and of all, in 4 cases the difference between the two formulas was below 1%.

There was no statistical difference between the two variables, Student's t-test p-value=0.039.

Discussions

The diagnosis, treatment, and follow-up of benign and malignant prostate diseases depend on an accurate calculation of prostate volume.

Studies have shown that knowing the PSA density, and implicitly the prostate volume, are useful in stratifying the risk of clinically significant prostate cancer, together with the PI-RADS score [7,11-17].

Schoots et al. [18] demonstrated that intermediate-risk PI-RADS 3 lesions with PSA density <0.10ng/mL/mL have a 4% risk of clinically significant disease, low enough for imaging monitoring to be more motivated compared to biopsy.

In the event that this risk adaptation will be adopted by urologists, additional attention will be needed to calculate the prostate volume in the case of PI-RADS 3 lesions, but also PI-RADS 2 lesions, because the same paper showed that 18% of patients with PI-RADS 1 and 2 but with PSA density >0.2ng/mL/mL shows significant disease.

Although it is the most widely used formula for MRI volume determination, reports of the accuracy of the ellipsoid formula are mixed, there are studies that say it overestimates [19], as well as those that say it underestimates [10].

Our paper partially contradicts these statements, even if we included in the study only prostate MRI examinations without significant pathology, but we had to do so because otherwise it would have prevented us from calculating the segmental method with precision.

The PSA density partially loses its importance in the case of malignantly transformed prostates, so we consider this prior filtering of the examinations useful, the only defect being the relatively small number of cases used in the study.

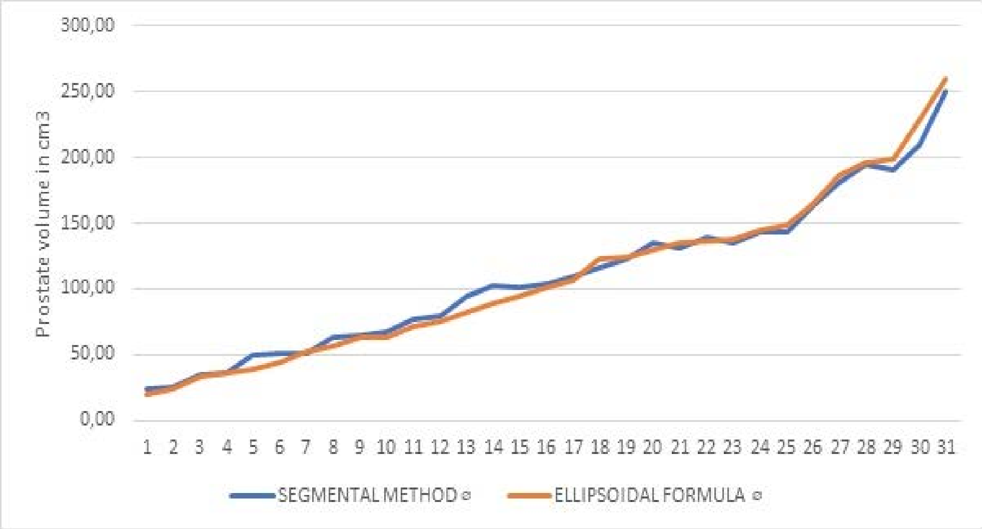

Figure 4. Blue line-the variation of the prostatic volume calculated by the segmental method; orange line-the variation of prostatic volume calculated by the ellipsoidal formula.

The tendency of the ellipsoidal formula was to underestimate the volume of normal and large prostates (<100cm^3) and to overestimate those of very large sizes (>100cm^3).

The overestimation can be attributed to the loss of the regular contour when they grow a lot in size, especially in the cranio-caudal axis (Figure 3 and 4), but the normal and large ones are underestimated exclusively due to the fact that the prostate is not a perfect ellipsoid, and the cases in which the ellipsoidal formula of estimated prostatic volume with an accuracy greater than 99%, we can consider them coincidental rather than effective.

Because the segmentation method is insidious, another alternative to calculating the prostate volume is the trained, high-precision software [20,21] that can suggest a second opinion when the PSA density is close to threshold values such as 0.1ng/mL/mL in PI-RADS 3 lesions or 0.2ng/mL/mL in PI-RADS 2 lesions.

Conclusions

With a precision of 92% (+/-6%), the ellipsoidal formula can be considered accurate when it is correctly performed, but if we take into account the importance that PSA density is starting to have in diagnosis, treatment and follow-up, the calculation of a secondary value through the segmentation method or high-precision software can be motivated when the ellipsoidal formula returns a value close to a threshold.

Conflict of interests

None to declare

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