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Novel ultrasound-based volume estimation of prostatic benign enlargement to improve decision-making on surgical approach

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Abstract

Aim: To assess the precision of preoperative ultrasonography (US)-determined prostate volume and to propose formulas for improving it.

Methods: This retrospective study comprised 155 consecutive men who underwent open prostatectomy for benign prostatic hyperplasia (BPH) between 2013 and 2019. Preoperative prostate volume was estimated by either abdominal US (AUS) ($n=92$) or transrectal US (TRUS) ($n=63$), and was compared with the weight of surgically enucleated tissue at a conversion rate of 1 ml (US) = 1 g tissue. Statistical analysis was conducted and a novel formula for prostate volume was constructed.

Results: The median prostate volumes by AUS and TRUS were 140 ml [interquartile ratio (IQR) 111–182] and 108 ml (IQR 93–120), respectively. Enucleated tissue weight was lower than the AUS assessment by a median difference of 50 g (IQR 28.7–75.7; $p<0.001$), and lower than the TRUS assessment by a median difference of 27 g, IQR 10–43, $p<0.001$). Using a cutoff of 80 ml, 30 (33%) AUS patients and 23 (36%) TRUS patients underwent unneeded open procedures. Mathematical calculations revealed two formulas that significantly adjusted for the actual weight: 1.082*Age + 0.523*AUS – 53.845 for AUS and 0.138*age + 2.22*prostate-specific antigen + 0.453*TRUS + 11.682 for TRUS ($p<0.001$). These formulas increased the overall US prostate volume accuracy from 65% to 85%.

Conclusion: Assessment of prostate volume by US is imprecise for decision-making of whether to perform open simple prostatectomy for BPH. Our novel formulas may enhance stratification of patients with prostatic enlargement to a more optimal surgical approach. Future studies in larger cohorts are needed to substantiate our results.

Keywords: accuracy, BPH, prostate volume, SPP, US

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Introduction

Surgery remains the standard of care for benign prostatic hyperplasia (BPH) in men with ineffective medical therapy and those with secondary complications (e.g., urinary retention, infection, bleeding, bladder calculi).[1] The past two decades have witnessed a trend toward expansion of transurethral BPH operations and other minimally invasive alternatives, while open prostatectomy is reserved mostly for high-volume prostates.[2] Despite this trend, European Association of Urology (EAU) guidelines still recommend open prostatectomy or transurethral endoscopic enucleation for prostates larger than 80 ml.[3] Thus, an accurate stratification by BPH volume may contribute to the choice of the most appropriate approach.

Estimation of prostate volume can be done by either a digital rectal examination or by imaging studies. The former is the simplest way to assess prostate volume, and it is performed as part of the physical examination in all candidates for surgery, but its correlation to true prostate volume is poor.[4] Magnetic resonance imaging (MRI) and computed tomography (CT) are probably the most precise assessments of prostate volume; however, they are preferentially reserved for prostate cancer cases.[4] In daily practice, abdominal ultrasound (AUS) or transrectal ultrasound (TRUS) are used for volumetric measurements of BPH. However, to the best of our knowledge, there is a paucity of evidence regarding the preciseness of US in assessing prostate size prior to simple prostatectomy.

In this study, we aimed to determine the accuracy of preoperative AUS and TRUS in predicting prostatic volume prior to selecting the surgical approach for BPH, and to construct a formula to effectively correct the estimated result.

Methods

The study was approved by the Tel Aviv Medical Center Review Board (ethical approval ID-TLVMC-663), which waived the need for informed consent. A retrospective survey identified all 176 patients who underwent suprapubic prostatectomy (SPP) for BPH during 2013–2019. Patients who were assessed by either AUS ($n=92$) or TRUS ($n=63$) prior to surgery were included in the study ($n=155$). Demographic and clinical characteristics collected for analysis included age, US-estimated prostatic volume (ml), weight of enucleated tissue as given on pathological reports, prostate-specific antigen (PSA), length of hospital stay, and complications according to the Clavien–Dindo classification.[5]

US volume evaluation

Prostate volume was estimated by AUS or TRUS by means of the ellipsoid volume formula (length × width × height × π /6).[6] We used the conversion rate of 1 ml (US) = 1 g tissue, which was validated elsewhere.[7,8] AUS was performed and evaluated by radiologists, and TRUS was performed and evaluated by urologists.

Surgical intervention

All of the study patients underwent SPP through a horizontal suprapubic incision under either general or spinal anesthesia. The bladder was exposed in the retropubic space, a vertical cystostomy was done between stay sutures, and the ureteral orifices were marked with 5 Fr feeding tubes. The bladder neck mucosa was circularly incised, the surgical capsule was identified, and manual *en bloc* enucleation of the adenoma was performed. The operation was completed with hemostatic sutures and closures in layers, leaving a three-way catheter in place for 4–5 days. Complete removal of all adenoma was confirmed and the enucleated tissue was weighed in the operation room immediately after resection.

Statistical analysis

Prostate volumes and weights lower than 80 g were considered suitable for transurethral resection and those ⩾80 g for open prostatectomy. That cutoff was used for statistical analysis and formula calculations. The formulas were then validated for 80 g and 100 g cutoffs. Descriptive statistics were used to summarize patient characteristics. Continuous variables were evaluated for normal distribution using histograms and Q–Q plots. Normally distributed continuous variables were reported as mean and standard deviation (SD), while other variables were reported as median and interquartile range (IQR). Continuous variables were compared between time points by the Wilcoxon test. Continuous variables were compared between categories with the independent samples t test or Mann–Whitney test. Pearson correlation coefficient compared the correlation between volume and weight. Logistic regression models were built with US estimations and patients' characteristics to define the most accurate preoperative formulas compared with the true weight. All statistical tests were two-sided, and $p < 0.05$ was considered statistically significant. SPSS software was applied for all statistical analyses (IBM SPSS Statistics, version 25, 2017, IBM Corp., Armonk, NY, USA).

Results

The demographic and clinical characteristics of the study group are presented in Table 1. The median hospitalization time was 7 days (IQR 6–8), and six patients (4%) sustained major complications (Clavien–Dindo 3 or higher). Four patients (3%) were diagnosed with T1a (small focus of Gleason 6 prostate cancer). The median AUS volume was 140 ml (IQR 111–182) and the median weight of the enucleated tissue for the entire cohort was 95 g (IQR 66–121). Comparisons of estimated AUS volumes to enucleated tissue weights resulted in a statistically significant

Table 1. Patients' characteristics ($n=155$).

	AUS group ($n=92$)	TRUS group ($n=63$)	*p* value	Overall ($n=155$)
Age (years) mean (SD)	74.2 (8.2)	73.9 (8.6)	$p=0.13$	74.1 (8.6)
PSA (ng/dl) mean (SD)	9 (13.8)	9 (13.7)	$p=0.8$	9 (13.8)
Preoperative US volume (ml) median (IQR)	140 (111–182)	108 (93–120)	$p<0.001$	120 (100–150)
Enucleated tissue weight (g) median (IQR)	95 (66–121)	95 (71–111)	$p=0.11$	95 (70–118)
Median difference between US volume and enucleated tissue weight, (IQR)	50 (29–76) $p<0.001$	27 (10–43) $p<0.001$	N/A	N/A

AUS, abdominal ultrasonography ; IQR, interquartile range; N/A, not available; PSA, prostate-specific antigen; SD, standard deviation; TRUS, transrectal ultrasonography; US, ultrasonography.

median difference of 50 g (IQR 28.7–75.7, $p<0.001$). Stratifying by the 80 g cutoff for justified open surgery, it emerged that 30 patients (33%) who underwent an open procedure were suitable for a transurethral approach. The correlation between the AUS and the enucleated weight was $r^2=0.614$ ($p<0.001$), and the accuracy of AUS in predicting the appropriate operation was 67%.

The median TRUS volume was 108 ml (IQR 93–120), while the median weight of the enucleated tissue was 95 g (IQR 71–111), yielding a statistically significant median difference of 27 ml/g, (IQR 10–43; $p<0.001$). At the cutoff of 80 g, 23 patients (36%) who underwent an open procedure were actually suitable for a transurethral approach. The correlation of TRUS values to enucleated weight was $r^2=0.4$ ($p=0.001$), and the accuracy of TRUS in estimating the right operation was 63%.

Mathematical models revealed that the most accurate formula for adjusting AUS measurements to the expected enucleated weight was 1.082*Age + 0.523*AUS − 53.845. Reassessment of the AUS group with this formula resulted in a statistically significant reduction in the difference between the AUS estimation and the actual enucleated weight to a median of 19 g ($p<0.001$). As such, only 13 patients would have undergone simple prostatectomy while being more suitable for transurethral prostatectomy, translating into an increase of AUS accuracy in weight prediction from 67% to 86%. The adjustment formula calculated for the TRUS group was 0.138*age + 2. 22*PSA + 0.453*TRUS + 11.682. Application of this formula to the TRUS group resulted in a statistically significant reduction of the median difference between the TRUS evaluation and the actual enucleated weight to a median of 7 g ($p<0.001$). In that case, only 11 patients would have undergone simple prostatectomy while being more suitable for transurethral prostatectomy, with an improvement in TRUS accuracy from 63% to 83%. At a cutoff of 100 g, 38 (40%) AUS patients and 22 (35%) TRUS patients would have been treated by unnecessary open surgery. Validating the formulas at a 100 g cutoff resulted in an increase from 59% to 89% for the AUS accuracy and from 65% to 94% for the TRUS accuracy (Figure 1).

Discussion

There is a growing interest in various minimally invasive procedures for the surgical treatment of benign prostate glands, some extending to all BPH patients without volume limits.[9,10] However, the decision of whether to perform transurethral or open surgery often still depends on preoperative estimation of prostate volume, surgeon expertise in transurethral procedures, and availability of advanced instruments (e.g., bipolar resectoscopes, lasers, morcellators, etc.). The trend towards a preference for transurethral procedures over open approaches is supported by advantages that include better esthetic outcome (no incision), shorter time of postoperative catheterization and hospital stay, and faster recovery.[11] An accurate preoperative estimation of prostate volume is essential for deciding the most suitable approach for a given patient. That measurement will allow surgeons to adhere to guidelines,[3] or to expend their transurethral limit according to their expertise.

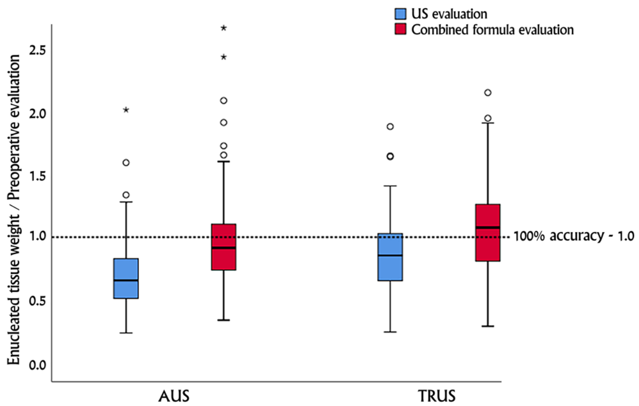

Figure 1. Box-and-whisker plot showing ratios of enucleated tissue weight and preoperative estimated volumes where the dashed horizontal line at level 1.0 represents 100% accuracy, and AUS and TRUS boxes represent the overall estimation before and after applying the adjusting formulas. The 25th and 75th percentiles are provided at the bottom and top of the boxes, respectively. The horizontal lines inside the boxes indicate median values.
AUS, abdominal ultrasonography; TRUS, transrectal ultrasonography; US, ultrasonography.

While the evaluation of prostate volume by means of AUS or TRUS is supported by international guidelines and is very common in daily practice, its reliability in predicting accurate prostate size prior to a simple prostatectomy is open to question. The results of our current study demonstrated that both AUS and TRUS carry an accuracy of only about 65%, thus defining a significant percentage of patients as candidates for unnecessary open prostatectomy. Trials to differentiate between the transition zone, the prominent location of benign hyperplasia, and the peripheral zone, which is not removed when surgically treating BPH, have been reported; however, all of these studies included men with prostate cancer.[12,13] Evidence for the applicability of these findings to BPH, especially in cases of very large glands, is not conclusive.

Our rationale for embarking on this study was that the process of digital enucleation follows the definitive plane of the surgical capsule, and it results in the removal of the entire enlargement associated with prostatic hyperplasia. As a result, we could rely on the enucleated tissue weight as the referral standard for assessing the reliability of the preoperative US. In addition, by using a mathematical methodology, we were able to provide formulas that significantly improved the preoperative AUS and TRUS volume estimation. No doubt that surgeons who can unlimitedly operate transurethrally may not need our novel proposed tools for decision making.[14–16] However, they, too, can use this information for logistic preplanning in terms of operative time. We concede that our proposed corroboration of age, AUS, TRUS, PSA, and coefficients might look difficult to memorize. However, once integrated into a computerized automatic tool – even a simple commercially available one – their routine use will be much easier. We adopted the formulas as a built-in feature of our departmental website (referenced in the supplemental material).

MRI and CT are valuable and reliable tools in the evaluation of prostate volumes when compared with the actual weight of prostates that had been entirely removed for surgical cancer treatment.[17–20] Despite good correlations in this context, it should be kept in mind that these prostates are weighed together with the seminal vesicles before pathological processing. Moreover, these imaging modalities are reserved to prostate cancer staging, they are more expensive, and they are less readily available for mass assessment, making their liberal use in cases of BPH less practical. As previously mentioned, US is currently the main tool for BPH volume estimation, and TRUS is reportedly more accurate than AUS in predicting prostate weight.[21] US may also enable the urologist to measure the transitional zone (“adenoma”) and not the entire gland (albeit not very common in daily practice).[22] In general, it should be borne in mind that TRUS is still a more invasive and inconvenient method for the patient.[23]

Future studies in larger cohorts are needed to substantiate our results. We must stress that our two new formulas were used in estimating only the BPH component of the prostate and not the entire gland and therefore may not be useful in diagnostics of prostate cancer patients (for instance in calculating PSA density).

We are aware that our study is limited by its retrospective design and the lack of measurements of both US modalities for each patient. In addition, the AUS studies were not performed under standardized conditions, various types of machines were used, and the results were interpreted by different radiologists. As such, we were probably inevitably exposed to inter- and intraobserver variability bias, as reported in the literature.[24] We also had data regarding ellipsoid volume estimations only, while some support the use of the “bullet” formula.[25] We could not compare our results with other imaging modalities.

Despite these limitations, we believe that applying our study protocol to a cohort of consecutive patients represents a real-life urological practice and mitigates some of these limitations.

The accuracy of US in evaluating preoperative prostate volume is modest. We provide ways to improve it by mathematical adjustment formulas using US volumes, patient age, and/or PSA values, and correcting coefficients. Although their application may already spare a significant number of BPH patients from unnecessary open surgery, the search for better modalities of volumetric assessment remains indispensable for further improvement of preoperative decision-making.

Author contributions

Conceived & Designed the Analysis, Wrote the Paper, S.D.; Collected the Data, S.D., E.S. and R.M.; Performed the Analysis, Y.B-Y. and R.M. Conceived and Designed the Analysis, O.Y. and M.S.; Wrote the Paper, M.S.

Conflict of interest statement

The authors declare that there is no conflict of interest.

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Supplemental material

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