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Validation of supra-pubic ultrasonography for preoperative prostate volume measurement in sub-Saharan Africa

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Abstract
Background Advances in urological techniques in sub-Saharan Africa need to be supported with practical ancillary diagnostics. This study aimed at determining the accuracy of suprapubic ultrasonography (SPUS) relative to transrectal ultrasonography (TRUS), the current gold standard, in estimating preoperative prostate volume in a sub-Saharan African hospital.
Methods Cross-sectional study of prospectively enrolled patients with severe lower urinary tract symptoms and histologically confirmed benign prostatic hyperplasia. The volume of the prostate was estimated using two modalities, SPUS and TRUS. Open prostatectomy was performed on all patients, and the mass of the enucleated prostate adenoma was measured directly.
Results Fifty patients were enrolled, with a mean age of 69 years. The mean prostate volume as determined by TRUS, SPUS, and direct measurement of enucleated prostatic tissue was 96.0, 95.9 and 83.5 mL, respectively. Prostate volume determined by SPUS correlated strongly with the TRUS measurement ($\rho = 0.98$, $P < 0.001$). The mean difference between the volume estimates by TRUS and SPUS was 0.09 mL [95% CI −2.07 to 1.89, $P = 0.93$], with upper and lower limits of agreement of −13.8 and +13.6 mL, respectively. Sensitivity, specificity, positive and negative predictive value for SPUS relative to TRUS for classifying patients according to the indication for TURP (prostate volume ≤80 mL) versus open prostatectomy (>80 mL) were 95% or higher. The volume of the enucleated adenoma was less than the volume estimated by ultrasonography by approximately 12.5 mL.
Conclusion SPUS is accurate relative to TRUS in assessing preoperative volume of the prostate and can be used in the African context to assign patients to open prostatectomy or TURP.

Keywords Diagnostic accuracy · Benign prostatic hyperplasia · Supra-pubic ultrasonography · Transrectal ultrasonography · Transurethral resection · Prostate

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Background

Benign prostatic hyperplasia (BPH) is one of the three most common diseases among men, and the most common neoplasm in older men [1]. It is found in 50% of men in their fifties and 80% of men beyond 70 years, both in developed and developing countries

[2, 3]. In Uganda, like in most sub-Saharan African countries, the disease prevalence is not known, although patients with BPH form the bulk of urology workload in our center.

Management options for BPH include pharmacologic therapy, transurethral resection of the prostate (TURP), and open prostatectomy. Prostate volume measurement provides critical information for guiding the choice of therapy: pharmacological therapy (prostate volume <40 mL), TURP (prostate volume 40–80 mL) or open prostatectomy (prostate volume >80 mL) [4, 5]. However, modalities for prostate volume estimation are either inaccurate (e.g., digital rectal examination) or unavailable in many resource-limited settings [e.g., transrectal ultrasonography (TRUS), cystoscopy, magnetic resonance imaging (MRI)] [6]. The gold standard TRUS is also discomforting, especially in patients with anal diseases such as hemorrhoids, anal fissures, and anal fistulae, as well as patients with a low-pain threshold. On the other hand, suprapubic ultrasound (SPUS) is more widely available, acceptable and affordable [7, 8] but requires validation against accepted gold standard imaging modalities in resource-constrained settings.

Advances in the surgical management of BPH such as transurethral resection of the prostate (TURP) have been not been widely adopted in hospitals in sub-Saharan Africa to date [9], mainly due to barriers in the availability of equipment, inadequate number of trained personnel conversant with the procedure, and lack of supportive diagnostic tools. Our referral center in urban Uganda currently performs open prostatectomy on most patients but is moving toward adoption of less-invasive techniques like TURP. Appropriate use of diagnostic imaging modalities may reinforce local capacity for modern surgical techniques including TURP. Simple, acceptable procedures such as SPUS, if validated, would therefore provide an attractive option for prostate volume estimation at our center and in other resource-constrained settings across sub-Saharan Africa.

The purpose of this study was to determine the accuracy of SPUS compared to TRUS in estimating preoperative prostate volume in a cohort of adult men with advanced BPH. We also determined the correlation and agreement between estimates obtained by the ultrasound modalities and compared both SPUS and TRUS to the directly measured volume of the surgically enucleated prostatic adenoma.

Methods

We prospectively enrolled fifty consecutive adult male patients with symptomatic BPH and an International Prostatic Symptom Score (IPSS) > 20, with subsequent postoperative histologic confirmation of BPH. Patients were enrolled from November 2009 to April 2010 at Mulago National Referral Hospital in Kampala, Uganda. Mulago Hospital is a severely resource-constrained tertiary care center that receives referrals from across Uganda.

All patients had prostate volume estimated by both TRUS (gold standard) and SPUS. The same radiologist estimated the volume of prostate by SPUS then TRUS on the same day using the ellipsoid formula. All patients subsequently underwent open prostatectomy, and the mass of the enucleated prostate adenoma was measured. The volume of the enucleated prostate adenoma was determined by assuming a tissue density of 1 g/mL.

Descriptive and comparative statistics were used to compare prostate volume determined by different ultrasound modalities and across subgroups. Correlation between SPUS and TRUS estimates was computed. Between-test agreement was assessed using Bland–Altman plots [10].

Results

Demographic and clinical characteristics

The median age was 70 years (range 51–91 years). The median BMI was 23.3 kg/m^2 (range 19.4–36.5) and 26% of the participants were overweight. The mean blood pressure at admission was 134 mmHg [range 110–188] (systolic) over 76 mmHg [range 60–110] (diastolic). Mean hemoglobin level was 126 mg/L (range 115–136).

Comparison of preoperative prostate volume measurement by SPUS and TRUS

The prostate volume estimated by ultrasound (SPUS and TRUS) is given in Table 1. The average volume was 95.9 and 96.0 mL by SPUS and TRUS, respectively, which was not statistically significantly different ($P = 0.93$). Prostate volume was larger in patients with body mass index (BMI) $\geq$ 25 kg/m^2

Table 1 Statistics of preoperative volumes (mL) of prostate by SPUS and TRUS

Factor	SPUS mean (SD)	TRUS mean (SD)	Difference mean (SD)	*P* value[a]
Overall	95.89 (51.38)	95.98 (51.55)	0.09 (6.98)	0.93
BMI < 25	81.65 (25.66)	81.60 (79.99)	0.05 (7.49)	0.98
BMI ≥ 25	136.44 (79.99)	136.91 (80.62)	0.47 (2.98)	0.60
Age 50–70	98.45 (58.40)	97.19 (57.79)	1.26 (8.17)	0.37
Age 71–91	93.13 (43.62)	94.67 (45.02)	1.54 (5.19)	0.32

[a] Paired *t* test

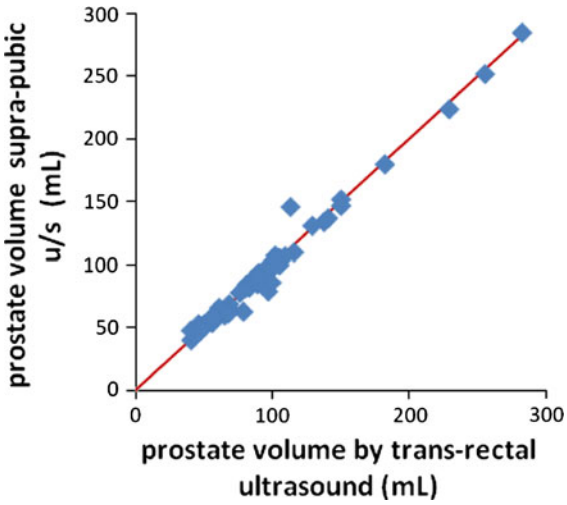

Fig. 1 Correlation between preoperative prostate volume measurement by two ultrasound modalities (SPUS and TRUS). Spearman's rank correlation coefficient $\rho = 0.98$, $P < 0.001$

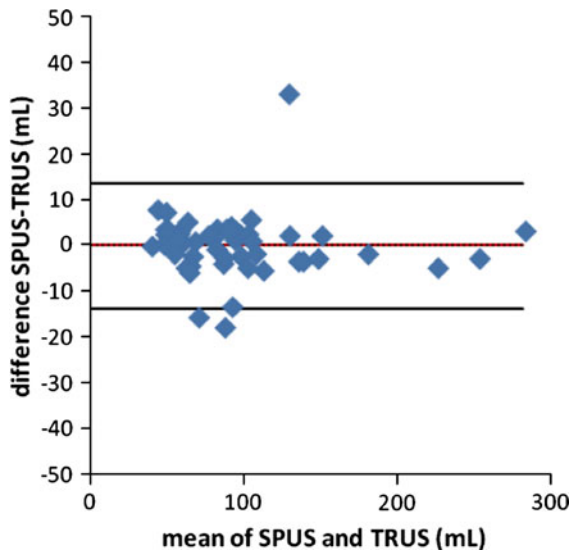

Fig. 2 Bland–Altman plot of the differences between measurements against the mean of the measurements. The mean of differences (*bias*, *red line*) is close to zero. The *upper* and *lower* limits of agreement were −13.8 and +13.6 mL, respectively

and in younger patients (age 50–70). Average prostate volume determined by SPUS and TRUS was similar across age and BMI subgroups (Table 1).

Correlation between suprapubic ultrasonography prostate estimates

There was a strong correlation between preoperative prostate volume measured by SPUS and TRUS (Fig. 1, Spearman's rank correlation coefficient $\rho = 0.98$, $P < 0.001$).

Bland–Altman analysis of agreement between SPUS and TRUS

Figure 2 shows the Bland–Altman plot of differences between SPUS and TRUS measurements against the mean of the measurements. The bias of SPUS relative to the TRUS was −0.09 mL [95% CI −2.1 to 1.9 mL, $P = 0.93$]. The limits of agreement between the methods were upper limit +13.6 mL [95% CI 10.1–17.0 mL] and lower limit −13.8 mL [95% CI −17.2 to −10.3 mL].

Diagnostic accuracy of SPUS Relative to TRUS (gold standard) for assignment of patients to transurethral resection of the prostate (TURP) versus open prostatectomy

A prostate volume less than of 80 mL is an indication for TURP [1]. We examined the ability of the SPUS to correctly assign patients to TURP relative to TRUS as the gold standard preoperative imaging modality.

Table 2 Sensitivity and specificity of SPUS to detect prostate volume ≤80 mL in relation to TRUS

Prostate volume estimates by SPUS	Prostate volume estimates by TRUS	
	TURP indicated (≤80 mL)	Open prostatectomy indicated (>80 mL)
SPUS predicts TURP (≤80 mL)	21	1
SPUS predicts open prostatectomy (>80 mL)	1	27
	22	28

The two-by-two classification table is shown in Table 2. Of the 22 prostates measured as ≤80 mL by TRUS, SPUS also determined the volume to be ≤80 mL in 21 patients and incorrectly classified one patient. The sensitivity of SPUS to detect prostate volumes amenable to TRUS was therefore 21/22 = 95% [95% CI 78–99%]. Of the 28 prostate volumes which were >80 mL by TRUS, SPUS agreed in 27, giving a specificity of 27/28 = 96% [95% CI 82–99%]. The positive and negative predictive values were 95% [95% CI 78–99%] and 96% [95% CI 82–99%], respectively.

Comparison of preoperative ultrasound measurements (TRUS and SPUS) with enucleated prostate volume

Figure 3 shows the agreement between the direct measurement of prostatic tissue resected at the time of surgery and the preoperative volume estimate by ultrasound (TRUS and SPUS). Of note, the enucleated prostate volume was systematically lower than ultrasound measurements (bias −12.5 mL [95% CI −9.1 to −15.9 mL, $P < 0.001$] and −12.4 mL [95% CI −8.2 to −16.6 mL, $P < 0.001$] versus TRUS and SPUS, respectively).

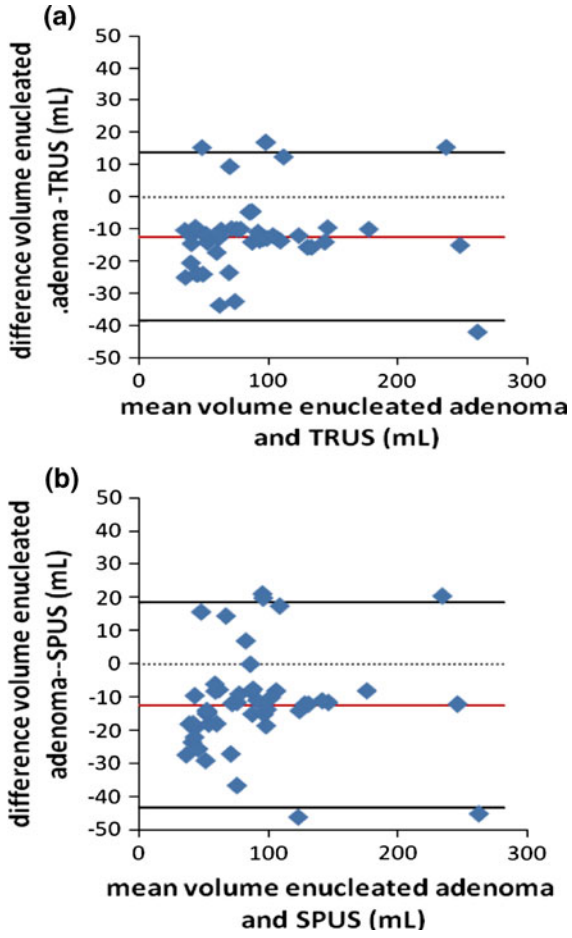

Fig. 3 Bland–Altman plots of the agreement between enucleated prostate volume and preoperative ultrasound measurements by TRUS (**a**) or SPUS (**b**). Differences between measurements are plotted against the mean of the measurements. The mean difference (*bias*) between volume of the enucleated adenoma and the preoperative prostate volume estimate was −12.5 and −12.4 mL for TRUS and SPUS, respectively

Discussion

SPUS is an attractive alternative to TRUS in the assessment of prostate volume because it is simple, less invasive, more acceptable to patients, and more widely available. Our findings indicate that SPUS can be used in a resource-constrained setting to provide an accurate preoperative estimate of prostate volume relative to the gold standard modality, TRUS. As such, SPUS shows promise as a modality to support modern surgical techniques like TURP for the management of BPH in sub-Saharan Africa.

This study found a strong correlation ($\rho = 0.98$) between the preoperative volume of prostate using SPUS and TRUS, as in previous studies [5, 7, 8, 11–14]. Agreement between modalities was also strong, based on Bland–Altman analysis [10], with zero bias and upper and lower limits of agreement less than ±15 mL. Previous studies have similarly shown negligible bias between SPUS and TRUS [8]. Other

studies found somewhat larger difference in means of prostate volume between SPUS and TRUS of 10 mL [12] and 8 mL [7], which might be explained by radiologist experience or patient characteristics. Preoperative assessment of prostate volume assists clinicians in assigning patients to TURP or to open prostatectomy. Using a threshold of 80 mL, the sensitivity, specificity, positive and negative predictive values of SPUS were 95% or more, relative to TRUS. This suggests that the appropriate surgical approach can comfortably be chosen based on SPUS estimation of prostate volume.

Overall, prostate volumes found in this study were among the highest in the published literature. A systematic review including 16 high-quality studies and 12, 158 patients found that the mean volumes reported in the literature varied from 33.9 to 61.0 mL [15], compared to 96 mL in our study. We postulate that this may be due to delay in seeking professional help and lack of access to health care, consistent with previous reports from Africa [9].

Obesity is a determinant of prostate volume and may confound its measurement. The mean prostate volume in this study was significantly higher among overweight patients. Obesity and diet are well-documented risk factors for BPH [16]. Furthermore, obesity may interfere with suprapubic measurement of prostate volume. However, in our study, SPUS agreed closely TRUS in the subgroup of obese patients (BMI $\geq$ 25 kg/m^2, representing 26% of the cohort).

Some previous studies have showed that correlation between TRUS and SPUS is weak in small prostates and becomes stronger in prostates over 50 mL [17]. In contrast, others have reported that larger prostates might make the dimension measurements difficult on SPUS, especially because of the difficulty in the determination of the caudal end of the prostate [7]. In our study, 48/50 prostates were larger than 50 mL, and we observed a strong agreement between SPUS and TRUS measurements that did not appear to vary across the spectrum of prostate volumes (Fig. 2).

The volume of the enucleated adenoma was approximately 12 mL less than the preoperative ultrasound estimates by either SPUS or TRUS. Similarly, Kanao et al. compared the volume of the whole prostate and the weight of the enucleated adenoma on 23 Japanese patients with BPH and found a difference of 21 mL between preoperative prostate volume and volume of enucleated adenoma [13]. Incomplete removal of the adenoma or volume overestimation by ultrasound techniques may explain this discrepancy. Nonetheless, in our study and others, there is a strong correlation between the volume of enucleated adenoma and the preoperative estimates [17–19].

Some of the limitations of this study include the assessment of the prostate volume using both SPUS and TRUS by the same radiologist, which may lead to the underestimation of differences between the ultrasound modalities. On the other hand, the accuracy of the ultrasound measurements is suggested by the high degree of correlation with the independently determined postoperative prostate mass. All patients underwent open prostatectomy in this study, consistent with the established local practice, whereas it would also be of interest to examine the outcomes in patients assigned to TURP or open prostatectomy using alternative preoperative modalities. The study is also limited by the relatively small number of patients at a single center.

In conclusion, SPUS is as accurate as the TRUS in assessing preoperative volume of prostate among symptomatic BPH patients in a sub-Saharan African context. SPUS has excellent sensitivity, specificity, positive and negative predictive values for assigning patients to TURP relative to TRUS as gold standard. Both ultrasound modalities provide prostate volume measurements that are larger than the volume of surgically enucleated prostatic adenoma.

Competing interest The authors declare that they have no competing interests.

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