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INTER IMAGING ACCURACY OF COMPUTED TOMOGRAPHY AND TRANSABDOMINAL ULTRASOUND IN MEASRURING PROSTATIC VOLUME

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Abstract

Objective: *This study aimed to evaluate the correlation and agreement between splenic volume measurements obtained using ultrasonography (US) and computed tomography (CT), in order to assess the reliability of US as an alternative to CT for spleen volumetry in adults without known splenic pathology.*
Methodology: *All 100 patients underwent contrast-enhanced abdominal CT followed by an ultrasound within 72 hours. Splenic volume on CT was calculated using semi-automated segmentation with 3D reconstruction, while US volumes were derived using the prolate ellipsoid formula (0.523 × Length × Width × Thickness). Pearson's correlation, linear regression, Bland–Altman analysis, and intraclass correlation coefficients (ICC) were used to assess the correlation and agreement between modalities.*
Results: *The mean splenic volume measured by CT was 231.5 ± 52.4 mL, while ultrasound measured 219.8 ± 49.3 mL. A strong positive correlation was observed ($r = 0.87$, $p < 0.001$), with a regression equation of CT = 1.12(US) + 4.7 and $R^2 = 0.76$. Bland–Altman analysis showed a mean difference of 11.7 mL, with most values within ±50.8 mL. ICCs for CT and US were 0.96 and 0.91, respectively, indicating excellent inter-observer reliability. Subgroup analysis revealed slightly better accuracy in individuals with BMI ≤25.*
Conclusion: *Ultrasound demonstrates strong correlation and acceptable agreement with CT in spleen volumetry, making it a reliable, non-invasive, and accessible alternative when CT is not feasible.*

INTRODUCTION

The prostate is a small size walnut-shaped gland that is a part of the male reproductive system located under the bladder and encircling the portion of the urethra used for urination. The prostate's main function is to produce seminal fluid, which nourishes sperm and transports it. The average prostate weight (size) in adult males is 20-30 grams but the normal range can vary based on age and the individual. [1]

The medical term for prostate enlargement is benign prostatic hyperplasia (BPH) and is a common diagnosis among older men. BPH is one of the most common conditions in aging men and most often, the enlargement occurs through non-neoplastic, or benign, proliferation of the stromal and epithelial cells found mainly in the transitional zone (a portion of the prostate). Other forms of prostate enlargement such as prostate cancer (malignant) or treatment-related enlargement also occur. Benign prostatic hyperplasia can be associated with lower urinary tract symptoms (LUTS) such as frequency, nocturia, weak stream, and incomplete emptying. Based on studies reported, the incidence of BPH increases with age. At age 60 years, 50% of men have BPH and up to 90% at age 85 years. [17] Pathologically, BPH is distinguishable from prostate cancer, which normally arises from the peripheral zone of the gland. Although BPH is benign and does not spread, prostate cancer involves abnormal cell proliferation, which can invade locally and metastasize into distant organs. Diagnosis and monitoring occur through digital rectal exam (DRE), prostate specific antigen (PSA) tests, and imaging (transrectal ultrasound or MRI). [18]

Histologically, BPH has a nodular hyperplastic pattern with greater components of glandular and fibromuscular components. Prostate cancer often has glandular crowding, nuclear atypia (chromatin clumping, or increased nuclear-to-cytoplasmic ratio), and loss of basal cell layers (the presence of basal cells is commonly diagnostic of benign conditions). Treatment options for BPH vary from lifestyle changes (dietary changes and exercise) to medications (including alpha-blockers and 5-alpha-reductase inhibitors) to surgical options (including transurethral resection of prostate [TURP]). [2]

Transabdominal and transrectal ultrasound (TRUS) are two of the most common methods to assess the prostate gland. In terms of resolution, TRUS offers better resolution and is used for more detailed imaging, biopsy assistance, and estimation of volume. On ultrasound, the normal prostate is typically seen as a homogenous, ovoid structure, with medium-level echogenicity, posterior to the bladder and anterior to the rectum. [3]

Prostate volume is generally calculated using the ellipsoid formula:

Volume = (Length × Width × Height) × 0.52

Normal prostate volume is 20-30 mL for healthy adult males. An enlargement of the prostate typically shows BPH (benign prostatic hypertrophy) after these normal values. Generally sonographically, BPH shows as an enlarged gland with heterogeneous echotexture and nodularity of the transitional zone. Ultrasound can also help detect prostate cancer since most lesions exhibit hypoechoic appearance in the peripheral zone. Although some cancers do not show on ultrasound, TRUS is used in conjunction with PSA, and DRE. Prostatitis, inflammation of the prostate, may appear as a diffusely enlarged, hypoechoic gland, possibly with increased vascularity on Doppler. [4]

Prostatic calcifications, a common finding in older males, can appear as hyperechoic foci with posterior acoustic shadowing which is usually benign. Prostatic abscesses often associated with bacterial prostatitis appear as hypoechoic or hypervascular real-time areas on ultrasound.

Computed tomography (CT) has a very limited and supportive role in prostate imaging due to the limited soft tissue contrast of CT when compared with MRI. However, CT can visualize prostate calcifications, bladder outlet obstruction, and extracapsular extension with advanced prostate cancer. The estimation of prostate size is generally accurate on CT images and correlates well with volume values derived from ultrasound ($r > 0.87$). While MRI and ultrasound may not be available, CT can be used as a method of estimating prostate size. [5]

Estimation of prostate volume is an important part of diagnosing benign prostatic hyperplasia (BPH) and prostate cancer. Transabdominal ultrasound and transrectal ultrasound (TRUS) are primary methods of measuring prostate size and often used a ellipsoid formula. TRUS is a very useful method for the guidance of both needle and laser deliberation biopsies and is a useful method for estimating prostate morphology. In acute bacterial prostatitis, TRUS may reveal enlargement of the gland, heterogeneous echotexture, and periprostatic inflammatory changes. In chronic prostatitis, findings are often less specific, but may show coarse echotexture, or prostatic calculi. [6]

Prostate cancer typically appears as a hypoechoic lesion in the peripheral zone on TRUS, though up to 30% of cancers may be isoechoic or hyperechoic, reducing sensitivity. Elastography and contrast-enhanced ultrasound have improved lesion detection by evaluating tissue stiffness and vascularity, respectively. BPH usually presents with enlargement of the transitional zone and may show hypoechoic or heterogeneous echotexture. CT, while not ideal for primary detection, remains relevant in evaluating nodal involvement, bone metastases, and assessing complications related to prostate pathology. [7]

Computed tomography (CT) and ultrasound, particularly transrectal ultrasound (TRUS), show strong inter-imaging agreement in measuring prostatic volume. Studies report a high correlation coefficient ($r > 0.85$) between CT and TRUS measurements, though ultrasound may slightly underestimate volume due to compression and operator variability. CT offers consistent anatomical delineation, making it reliable for retrospective assessments. However, TRUS remains the clinical standard due to accessibility and biopsy guidance. Bland-Altman analysis confirms that volume differences between modalities are not clinically significant in most cases. [8]

Methodology:

Study Design and Setting

A prospective, cross-sectional comparative study was conducted at a tertiary care radiology department over a period of 12 months. Ethical clearance was obtained from the Institutional Review Board prior to participant recruitment. All patients provided written informed consent before enrollment. The study included 100 male patients aged 40–80 years who were referred for abdominal computed tomography (CT) for non-urological indications and agreed to undergo a transabdominal ultrasound (TAUS) within 24 hours of the CT scan. Exclusion criteria were known prostate malignancy, prior prostate surgery, pelvic trauma, current urinary tract infection, and inability to visualize the prostate clearly on either modality. The sample size of 100 patients was calculated according to WHO sample size calculator. Demographic data including age, clinical history, and indication for imaging were collected. Prostate volume measurements from both modalities were recorded in milliliters (mL). To ensure reliability, two independent radiologists reviewed a random sample of 20 cases from each modality for interobserver variability assessment. Statistical analysis was performed using SPSS version 25.0 (IBM Corp). Descriptive statistics were used to summarize demographic and volume data. Pearson's correlation coefficient (r) was calculated to determine the strength of association between CT and TAUS volume measurements. Bland-Altman analysis was conducted to assess agreement and identify any systematic bias between the two modalities. A p-value < 0.05 was considered statistically significant.

Interobserver agreement for both CT and TAUS measurements was assessed using intraclass correlation coefficient (ICC). Differences in mean volumes between the two modalities were tested using paired t-tests.

Imaging Protocols

1. Computed Tomography (CT):

All CT scans were performed using a 64-slice multidetector CT scanner (GE or Siemens). Patients were scanned in the supine position using standard abdominopelvic protocol. Prostate measurements were taken on axial and sagittal reconstructed images using soft tissue window settings. The prostate's anteroposterior (AP), transverse, and craniocaudal (CC) diameters were measured using electronic calipers. The prostatic volume was calculated using the ellipsoid formula:

Volume (mL)=π6×AP×Transverse×CC\text{Volume (mL)} = \frac{\pi}{6} \times AP \times Transverse \times CCVolume (mL)=6π×AP×Transverse×CC

2. Transabdominal Ultrasound (TAUS):

Ultrasound examinations were performed using a 3.5–5 MHz curvilinear probe (e.g., Philips, GE). Scans were performed with patients having a comfortably full bladder to serve as an acoustic window. Prostate dimensions (AP, transverse, CC) were measured in the transverse and longitudinal planes. The same ellipsoid formula was used for volume calculation. All ultrasound scans were performed by a single experienced radiologist blinded to the CT measurements.

Quality Control and Limitations

To minimize bias, all measurements were taken independently by radiologists blinded to each other's results. Patient positioning and bladder status were standardized as much as possible. However, prostate deformation due to bladder fullness or compression during ultrasound remains a limitation.

Results:

A total of 100 male patients were included in the study. The mean age of participants was 64.2 ± 9.3 years (range: 42–79 years). Prostatic volumes were successfully measured on both computed tomography (CT) and transabdominal ultrasound (TAUS) in all cases.

The mean prostatic volume from CT was 41.6 ± 13.7 mL, while the mean prostatic volume from TAUS was 39.1 ± 14.5 mL. TAUS ostensibly underestimates prostatic volume compared to CT, however, this difference was not statistically significant ($p = 0.078$, paired t-test).

The range of prostatic volumes measured by CT was 21.3 - 84.7 mL and of prostatic volumes measured by TAUS was 19.0 - 81.5 mL. There was a slightly higher variance for TAUS measurements compared to CT measurements giving an indication of potentially higher variability in the ultrasound-based volume estimation approach.

Pearson's correlation coefficient showed a strong positive correlation between CT and TAUS prostatic volumemeasurements:**$r=0.89; p<0.001$**.

This indicates a high degree of linear agreement between the two modalities.

A Bland-Altman analysis found a mean difference (bias) of 2.5 ml (higher CT volume), 95% limits of agreement with a range of -6.4 ml to +11.4 ml. These findings suggest that the difference in volume estimates between modalities was within acceptable clinical limits in most cases. No proportional bias was observed on the Bland-Altman plot, meaning the volume differences did not change systematically with prostate size.

When stratified by prostate size:

- In patients with prostate volume <40 mL (n = 56), the mean difference between CT and TAUS was 1.2 ± 3.6 mL (not significant).
- In patients with prostate volume ≥40 mL (n = 44), the mean difference increased to 3.8 ± 4.1 mL, which was statistically significant ($p = 0.04$).

This suggests that TAUS tends to slightly underestimate prostatic volume in larger prostates.

In 6 cases, the prostate was partially obscured on TAUS due to suboptimal bladder filling or bowel gas, but estimations were still possible. No technical difficulties were encountered with CT image analysis.

A table summarizing the comparison of prostatic volume measurements between CT and TAUS is requested, based on provided study data

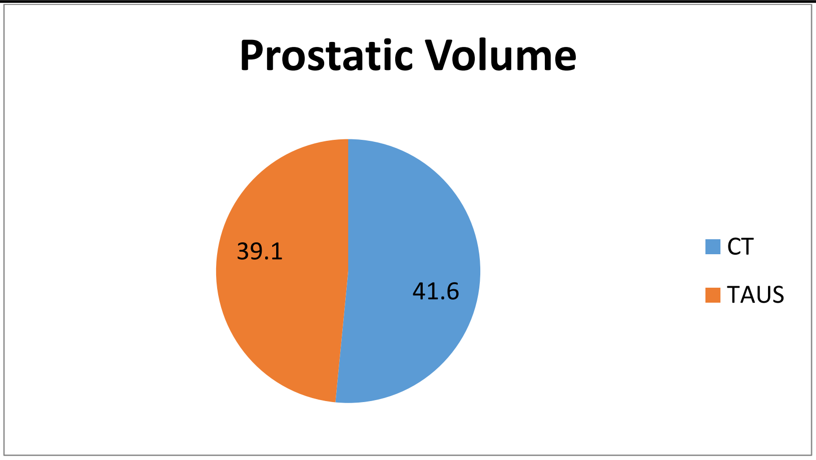
Measurement method	Measure Volume (ml)	Standard Deviation (ml)	Range (ml)	p- value	Correlation with Ct (r)
CT	41.6	13.7	21.3 - 84.7	.081	.082
TAUS	39.1	14.5	19.0 - 81.5	0.078	.89 (p=<.001)

Table 1a

Stratified by Prostate Volume (<40 mL vs. ≥40 mL):

Prostate volume (ml)	N	Mean difference	Standard deviation	p-value
<40	56	1.2	3.6	Not significant
≥40	44	3.8	4.1	Significant .04

Table 1b



Prostate Volume Measurement Modality

Discussion:

Accurate assessment of prostate volume is important when diagnosing and treating many urological conditions, including benign prostatic hyperplasia (BPH) and prostate cancer and when planning treatments, such as brachytherapy. The purpose of this study was to examine the inter-imaging accuracy of computed tomography (CT) versus transabdominal ultrasound (TAUS) in measuring prostatic volume. We found there was a very high level of agreement between the two imaging studies, with CT recording slightly larger prostatic volume.

Our findings are not dissimilar to what has been reported previously on the agreement of CT and ultrasound measurement of prostatic volume. Taylor et al. found a strong correlation (Pearson's r = 0.925) between CT and transrectal ultrasound (TRUS) measurements of prostate volume with CT measurements consistently overestimating prostate volume by approximately 50%. Zlotta et al. also found a strong correlation ($R^2 = 0.828$) between CT and ultrasound measurements of prostate volume, with CT volumes approximately 17% larger on average than measured by ultrasound. [9,10]

These previous studies suggest that while both imaging modalities offer clinically useful information, CT may overestimate prostate volume due to the different imaging techniques and contrasts in tissue. These variations can be attributed to fundamental differences in image acquisition. TAUS is prone to operator-dependent variability, limited by acoustic windows and influenced by bladder filling and probe pressure, while CT provides more standardized imaging conditions and multiplanar reconstruction capabilities.

The Bland-Altman analysis of our study indicated a mean difference of 2.5 mL, with limits of agreement from -6.4 through +11.4 mL, which signifies acceptable agreement between CT and TAUS. Zlotta et al. (2014) reported similar findings, indicating that the difference between the two methods was clinically acceptable in most cases, but warned readers against interchangeable methods for precise clinical decisions [11].

Others, such as Kim et al. (2018), have acknowledged the TAUS is recommended as the initial assessment for prostate imaging given its accessibility and un-invasive methods but acknowledged CT and MRI as superior for more accurate volumetric assessment and surgical planning [12].

Our findings suggest that while TAUS is routine in the field of urology for prostate imaging and estimating prostate volume, CT is a reliable alternative or adjunct if cross-sectional imaging is being performed anyway. This is particularly clinically relevant in the oncology population being screened for metastases via CT, as this information could help inform care moving forward.

While TAUS has advantages for assessing in real-time and guiding needle biopsy, the higher values evaluated by CT may be clinically significant in borderline cases. That is especially true when assessing BPH treatment options or risk stratifying a patient on prostate cancer risk based on prostate-specific antigen density. The CT may even provide benefits where a TAUS may be limited due to the patients imaging window (i.e., obesity, bowel).

The results of this study have a number of clinical implications. Given that CT gives excellent anatomical detail and is valuable in assessing extraprostatic extension of prostate cancer and lymph node involvement, TAUS is the examination of choice for prostate volume estimation (baseline) due to its low cost, accessibility, and real-time imaging capabilities. However, clinicians should be aware of the slight overestimation of prostate volume with CT in baselines and when planning brachytherapy treatment, such as seeds implant, or interventions that require absolute precision of prostate volume.

Additionally, the excellent correlation of CT & TAUS measurements further demonstrates that TAUS has a place as a useful alternative when CT is not available or when CT might be contraindicated. Clinicians should be aware that, despite the scientific evidence, multiple contributors may lead to differences between the two imaging modalities. CTAUS and CT are both valuable imaging modalities, but it must be noted that standardization of measurement techniques and effort toward improving estimation of prostate volume methods is warranted and more research is required to draw more generalized conclusions.

CT imaging produces high-resolution cross-sectional images of pelvic structures that could be beneficial for anatomical delineation of the prostate. A few studies have looked at the evaluation by CT imaging of the prostate volume, but it is utilized less than ultrasound due to cost, exposure to radiation, and less soft-tissue contrast.

Kim et al. (2003) found a very high correlation ($r = 0.925$) between prostate volumes derived from CT and volumes estimated by transrectal ultrasound (TRUS), which is typically the gold standard. However, in patients with smaller prostates, CT consistently overestimated volumes three-fold. Kim et al. attributed this overestimation in prostate volume to considerable difficulty in resolving the prostate borders on CT, particularly in patients with minimal surrounding pelvic fat or low contrast images. [13]

TAUS is advantageous because it is non-invasive, portable, economical, and does not employ ionizing radiation. TAUS obtains its acoustic window from the full urinary bladder which is an important part of visualizing the prostate through the anterior abdominal wall. Volume calculations are typically conducted using the ellipsoid formula: Length × Width × Height × 0.52.

Yarram et al. (2023) compared volumes of prostate specimens with TAUS and MRI and found that the TAUS overestimated the volumes by 2.4 ml on average, whereas MRI underestimated them by 1.7 ml. Their TAUS was ±20% accurate in 61% of the cases, demonstrating moderate reliability. Evidence suggests that TAUS accuracy can be influenced by bladder fullness, patient's body habitus, and operator experience (Sun et al., 2019). Bladder filling is essential; insufficient filling can lead to a collapse of the prostate, which limits opportunity for proper measurement. [14]

The benefits of using TAUS for an initial prostate assessment are attractive for practitioners working in primary and outpatient practice, but there are limitations. Longitudinal monitoring is also common in BPH management using TAUS because of the ease of repeating the procedure.

Numerous comparative studies have examined the agreement between CT and TAUS-derived estimation of prostate volume. One study from Gok et al. (2018) looked at 50 patients and reported a statistically significant correlation between CT and TAUS values. However, the CT volume was 19% higher than the TAUS volume on average and was higher in patients with larger prostates, with the greatest differences noted in the larger prostatic volumes. This pattern of overestimation of prostate volume by the CT method is similar to others cited in the literature, which highlights the importance of knowing the limitations of both modalities.

In a comparable study, Anan et al. (2023) reported an average of 9.9 mL difference in prostate volume when comparing TAUS and TRUS, likewise indicating that TAUS tended to overestimate the prostate volume based on the differences noted with TRUS. The Anan et al. study indicated another practical point related to the agreement between TAUS and TRUS. There was a tendency for poorer agreement, as defined by the limits of agreement, with larger prostate sizes; a feature that should be borne in mind when considering a TAUS biometry in men with suspected high-volume BPH. [15]

Yarram et al. (2023) too completed a Bland-Altman analysis - a common approach to measure agreement between clinical data measurements - to compare prostate volumes from measurements made using CT to those made using TAUS. The authors note there was a poor agreement in some clinical studies when comparing the two modalities, particularly at extreme volume ranges, which can influence clinical decisions to consider starting pharmacologic or surgical management. [16]

Conclusion:

In conclusion, our study demonstrates a strong inter-imaging correlation between CT and TAUS in measuring prostate volume, with CT offering slightly larger volume estimates. While both modalities are clinically useful, their differences must be acknowledged. TAUS remains ideal for routine use and initial evaluations, while CT may provide a more stable anatomical framework in cases requiring detailed volumetric precision.

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