COMPARATIVE ANALYSIS OF PROSTATE VOLUME MEASUREMENT USING TRANSABDOMINAL ULTRASOUND, TRANSRECTAL ULTRASOUND, AND MRI: A RETROSPECTIVE OBSERVATIONAL STUDY

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Abstract

Introduction: Prostate volume (PV) measurement is crucial for managing prostate conditions, including benign prostatic hyperplasia (BPH). Its range can be measured using different imaging modalities like transabdominal ultrasound (TAUS), transrectal ultrasound (TRUS), and magnetic resonance imaging (MRI) of the prostate, which were compared in this study.

Methods: A single tertiary centre retrospective observational analysis was conducted on PV measurements obtained through TAUS, TRUS, and MRI prostate from the same patients prior to biopsy. The mean of PV from each imaging modality was analysed using the Analysis of Variance (ANOVA) and a Tukey post hoc test, with $p < 0.05$ was considered statistically significant.

Results: Only 311 out of 718 patients who underwent TRUS biopsy from January 2018 until December 2022 were eligible for this study based on the inclusion criteria. The median age and PSA were 71 years old and 7.5 ng/mL, respectively. No significant difference was found across the means of the imaging modality and PV measurement among the imaging modalities ($F = 0.713$, $p = 0.49$). The Tukey post hoc test also revealed no significant difference between each modality, namely TAUS-TRUS ($p = 0.45$), MRI-TRUS ($p = 0.79$), and TAUS-MRI ($p = 0.85$).

Conclusion: This study demonstrated no statistically significant relationship in prostate volume measurements from the three different imaging modalities, namely TAUS, TRUS, and MRI.

Keywords: Magnetic Resonance Imaging, Prostate Volume, Transabdominal Ultrasound, Transrectal Ultrasound

Introduction

Prostate volume (PV) measurement plays an important role in managing prostate-related conditions, such as benign prostatic hyperplasia (BPH) and prostate cancer (PCa) (1). Traditionally, PV is estimated through digital rectal examination (DRE); however, it has a poor correlation to actual PV, especially when the prostate is larger than 30 ml (2). PV measurement is crucial for BPH to facilitate treatment planning, monitor the progression of disease or response to therapy, and select interventional treatment like open prostatectomy, enucleation, transurethral resection, or transurethral incision of the prostate. The estimation of PV can also serve as a predictor for BPH-related complications, such as urinary retention, obstructive uropathy, and renal injury (3). On the other hand, PV estimation in PCa and its correlation with a prostate-specific antigen (PSA) can aid in risk assessment and stratification. The mere usage of PSA level in PCa screening has resulted in the detection of more low-risk prostate cancer cases with no significant effect on its mortality (4). This will lead towards overdiagnosis with over treatment, resulting in unnecessary harmful side effects. Subsequently, significant developments have been introduced in the usage of PSA testing to increase the accuracy of detecting clinically significant prostate cancer (csPCa), which causes morbidity and mortality. This includes the use of PV measurement to calculate the prostate-specific antigen density (PSAD) (5).

Existing PV estimation methods range from the simplest DRE to different imaging modalities like transabdominal ultrasound (TAUS), transrectal ultrasound (TRUS), and magnetic resonance imaging (MRI) of the prostate. Various formula can be utilised to calculate prostate volume through the measurement of three different prostate dimensions: transverse (T), anteroposterior (AP), and longitudinal (L) diameter. The first two dimensions are often measured in the axial plane while the latter involves the sagittal plane. Many of the formulas assume that the prostate gland is an identical ellipsoid shape; hence, the equation of π/6 multiplied T x AP x L diameter is commonly used to calculate the prostate volume (6).

To date, no studies have established a comparison of PV measurement via TAUS, TRUS, and MRI. Therefore, this study aims to address such gap by comparing the PV measurement from three different imaging modalities, namely TAUS, TRUS, and MRI prostate.

Material and Methods

Study population

This study is a retrospective observational analysis of prostate volume measurements obtained through three different imaging modalities, namely TAUS, TRUS, and MRI prostate. The study population consisted of patients presented with elevated PSA (more than 4 ng/mL) and underwent all three imaging modalities for prostate evaluation prior to TRUS biopsy at Universiti Malaya Medical Centre (UMMC) from January 2018 until December 2022. A total of 718 patients underwent TRUS biopsy; however, only 311 patients were eligible for this study. The inclusion criteria included adult males with no previous history of prostate surgery and available records of prostate volume measurements from all three imaging modalities. The data was extracted from medical records and imaging databases. The following information was also obtained from each patient: age, serum PSA levels, prostate volume measurement from each modality, and the histopathological examination (HPE) result.

Prostate volume measurement

Prostate volume measurement was recorded in millilitres (ml) for each imaging modality. PV from TRUS was automatically generated by an ultrasound machine using the ellipsoid formula based on the transverse (T), anteroposterior (AP), and length (L) dimensions as determined by the performing urologist during the TRUS-guided biopsy. Meanwhile, PV from TAUS was measured by a senior medical officer in radiology with more than 4 years of experience. Finally, MRI-based PV was calculated from the maximum diameter of triplanes measurements of the prostate gland on high-resolution and focused field of view T2- weighted images using the ellipsoid (L × W × H × 0.52) formula from MRI prostate.

Statistical analysis

Descriptive statistics were used to summarise the demographic and clinical characteristics of the study population. Mean, standard deviation, median, and interquartile range were calculated for continuous variables, while frequencies and percentages were reported for categorical variables. The mean PV from each imaging modality was determined using the Analysis of Variance (ANOVA) and the null hypothesis stated that there was no significant difference in prostate volume measurement from each of the imaging modality ($p>0.05$). Patient confidentiality was maintained by deidentifying the collected data and assigning unique identification numbers to each patient. This retrospective study was reviewed by the institutional review boards and obtained ethical approval (MREC ID:2022917-11548).

Results

Only 311 out of the 718 patients who underwent TRUS biopsy during the study period were selected to partake in the research according to the inclusion criteria. The overall demographic and clinical characteristics of the patients are shown in Table 1. The median age was 71 years old, and PSA was 7.5 ng/mL. The patients were mainly Chinese (n = 201), followed by Malay (n = 84) and Indian (n = 26). The HPE results revealed adenocarcinoma (30%), chronic prostatitis (4%), and benign biopsy (66%). Finally, the mean of PV measurement was determined for TAUS (54.3 ± 26.4 ml), TRUS (51.8 ± 26.6 ml), and MRI (53.2 ± 28.1 ml).

Table 1: Baseline demographic and clinical characteristics of patients recruited for this study.

Variable	**n**	
Number of patients	311	
Age, years (mean±SD)	71 (44-88)	
PSA, ng/mL	7.5 (0.3-76)	
Race		
Malay	84	
Chinese	201	
Indian	26	
Imaging Modalities		
TAUS PV (mL)	54.3 ± 26.4	
TRUS PV (mL)	51.8 ± 26.6	
MRI PV (mL)	53.2 ± 28.1	
Histopathological Examinations	Right lobe	Left lobe
Adenocarcinoma	92	75
Chronic prostatitis	11	8
Benign	208	228

Table 1: Baseline demographic and clinical characteristics of patients recruited for this study (continued)

Variable	n	
Surgical Gleason group	(n = 92)	(n = 75)
6	24	14
7	33	22
8	13	20
9	21	18
10	1	1

Values were presented as mean ± standard deviation, number (%), or median (interquartile range). PSA, prostate-specific antigen; TAUS, transabdominal ultrasound; TRUS, transrectal ultrasound; MRI, magnetic resonance imaging; PV, prostate volume.

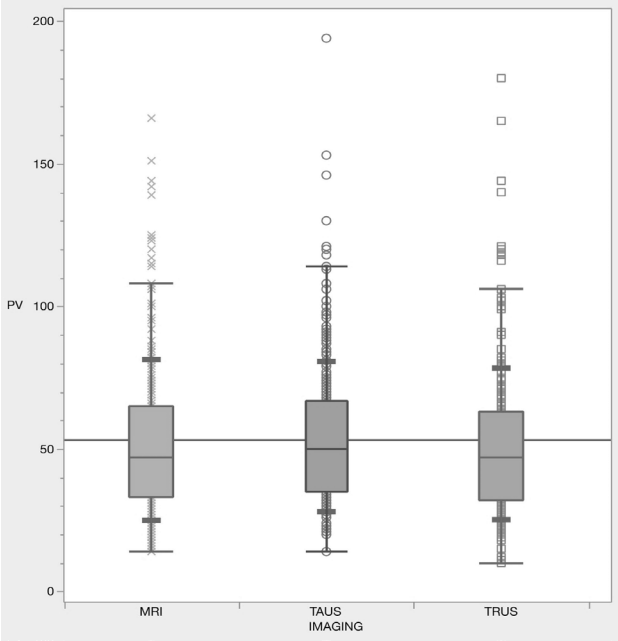

Figure 1: Prostate Volume measurement and outliers. Box and whisker plot shows median, 25th, and 75th percentiles as boundaries to each box with outliers indicated with individual symbols.

The ANOVA results found no statistically significant difference across the means of PV measurement for each imaging modality (F = 0713, p = 0.49). The Tukey post hoc test also revealed no significant difference between each modality, namely TAUS-TRUS (p = 0.45), MRI-TRUS (p = 0.79), and TAUS-MRI (p = 0.85).

Discussion

The measurement of prostate volume plays an important role in managing prostate disease. PV estimation among BPH patients aids in the monitoring of disease progression, predicting possible complications, and selecting the most suitable surgical intervention or procedure (7). Conversely, the estimation of PV in PCa patients can be useful in risk estimations and stratifications, particularly when combined with PSA level (8).

The most ideal method to assess PV accuracy is by comparing each imaging modality measurement with the actual specimen volume after radical prostatectomy (RP). This is possible in high-volume centres where there is a large number of RP performed and the availability of prostate specimens. In terms of managing prostate disease and planning or selecting the appropriate treatment, prostate volume is often estimated based on the most accessible imaging modality. This highlights the importance of reporting empirical evidence indicating no statistically significant differences in PV measurement for each imaging modality.

TAUS is the least complicated imaging method for measuring PV compared to TRUS and MRI as it is easily accessible, involves non-invasive procedures, and can be well tolerated by patients. It often stands as the primary imaging modality performed at a bedside or outpatient clinic setting when encountering patients with lower urinary tract symptoms. PV measurement can be easily calculated using the ellipsoid formula. Previous studies reported no statistically significant difference between TAUS and TRUS prostate volume measurements with similar patients (9).

Meanwhile, PV measurement via TRUS has been gaining popularity among urologists following its ability of assessing the prostate and performing procedures (i.e., biopsy and aspiration) simultaneously. Past studies reported a significant correlation on the average prostate volumes measured using TRUS and MRI (R = 0.801; p = 0.0001) (10). Due to its invasive imaging modalities, the procedure may cause anxiety and discomfort to people with anal diseases, such as haemorrhoids or anal fissures.

MRI has emerged as an integral imaging modality for prostate cancer investigation, leading to significant improvement in prostate volume measurement. The adoption of multiparametric MRI (mpMRI), which combines anatomical and functional imaging techniques, non-invasiveness, excellent soft tissue contrast, and multiplanar imaging capabilities, has contributed to its prominent growth in accurately assessing prostate volume. A prominent advantage of MRI is the ability to assess the volume of individual or separate zones in the prostate that are affected by different prostate conditions. MRI estimates prostate volume through several ways, with traditional ellipsoid measurement tends to overestimate prostate volume compared to the segmentation method (p < 0.0001) (11). Past studies showed the MRI estimation of prostate volume had a high correlation with post radical prostatectomy specimens (12, 13). Although MRI is an optimum imaging modality for prostate volume estimation, the high cost and limited access have made its usage limited, especially in peripheral or district centres.

Table 2: Post HOC Tukey-HSD test.

Modalities	Modalities	Difference	Lower CI	Upper CI	p-value
TAUS	TRUS	2.588424	-2.50508	7.681932	0.4577
MRI	TRUS	1.414791	-3.67872	6.508299	0.7913
TAUS	MRI	1.173633	-3.91987	6.267141	0.8511

Furthermore, MRI is mostly offered in tertiary centres due to the requirement of trained radiologists and expertise to operate the equipment. It is also not readily available for early imaging to estimate prostate volume. On the other hand, TAUS is considered the most suitable early imaging modality for prostate volume estimation in managing prostate conditions due to its non-invasiveness, radiation-free nature, and availability to primary or peripheral care. Although studies have shown that MRI is superior in estimating prostate volume than TAUS (14), the results of this study demonstrated no statistically significant relationship in the means of prostate volume estimation between the two imaging modalities ($p = 0.49$). This is vital to show that prostate volume estimation via TAUS is comparable to other more sophisticated imaging modalities. These findings also suggest the potential usage of TAUS as the primary imaging modality for prostate volume estimation in primary care for prostate disease. This will eventually aid in early referral for predicting the progression of disease in BPH or suspicions of clinically significant prostate cancer for patients with elevated PSA after calculating PSAD (15).

However, this retrospective study is not without limitations. First, the was a few months interval between the initial TAUS, MRI, and TRUS. This was due to the practice in our centre where the General Clinic Primary Treatment (GCPT) would initially attend to patients with LUTS or elevated PSA levels using TAUS as the initial imaging modality. Referral to the Urology Unit would only be made after reviewing the ultrasound, followed by the arrangement for MRI. Indications to proceed with TRUS and prostate biopsy would be conducted upon reviewing the MRI results and if any suspicious prostate cancer is present. Prostate volume may have changed during this period as some patients could have commenced their medications like 5-alpha reductase inhibitors, subsequently affecting the measurement. Second, even though the PV measurements from TAUS and TRUS were done by the senior medical officers in radiology and urologists with adequate experience, it might have certain effects on the interobserver variability.

Finally, this study is limited by the retrospective research design. Less than half of the patients were eligible to partake in the research due to incomplete documentation of all three imaging modalities performed prior to biopsy. Thus, a well-designed prospective study will be ideal to verify the findings.

Conclusion

This study demonstrates no statistically significant relationship in prostate volume measurements from three different imaging modalities: TAUS, TRUS, and MRI. A clinical implication of the results is using TAUS as an initial imaging modality for prostate volume estimations, especially in primary or peripheral centres where more sophisticated imaging of TRUS or MRI is limited.

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Competing interests

The authors declare that there are no competing interests.

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