

CLINICAL SIGNIFICANCE OF BLADDER WALL THICKNESS IN MEN WITH BENIGN PROSTATIC HYPERPLASIA USING TRANS ABDOMINAL ULTRASOUND

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Abstract

Background: Bladder wall thickness (BWT) may reflect structural changes in the bladder muscle that develop in response to chronic bladder outlet resistance in men with benign prostatic hyperplasia (BPH). Transabdominal ultrasonography offers a simple, radiation-free method for measuring BWT, but its relationship with symptom severity and disease duration has not been fully standardized.

Objective: To assess the association between transabdominal ultrasound-measured BWT and International Prostate Symptom Score (IPSS) severity, duration of BPH, prostate size, and sonographic BPH grade.

Methods: This cross-sectional study included 98 men with BPH at Services Hospital, Lahore. Transabdominal ultrasound was used to assess prostate size and BWT. BPH duration, sonographic grade, and IPSS were recorded. Data were analyzed using correlation, Kruskal–Wallis/Conover tests, and univariable regression.

Results: The mean age was 64.84 +/- 12.92 years (range 43-98). Age was positively correlated with prostate size ($r=0.3547$, 95% CI 0.1682-0.5168; $p=0.0003$). Median BWT varied across IPSS categories, measuring 5.0 mm in the mild group ($n=71$), 6.5 mm in the moderate group ($n=21$), and 6.0 mm in the severe group ($n=6$) (Kruskal-Wallis $H=25.19$, $df=2$; $p<0.001$). The mild group differed significantly from both the moderate and severe groups. BWT also showed a modest positive correlation with BPH duration ($r=0.3009$, 95% CI 0.1090-0.4712; $p=0.0026$). In exploratory linear models, prostate size and BPH grade were positively associated with BWT ($R^2=0.081$, $p=0.0045$ and $R^2=0.133$, $p=0.0002$, respectively).

Conclusion: Bladder wall thickness (BWT) was significantly associated with LUTS severity, disease duration, prostate size, and BPH grade.

1. INTRODUCTION

Benign prostatic hyperplasia (BPH) is among the most common benign conditions affecting older men and is a major cause of male lower urinary tract symptoms (LUTS). Its clinical

presentation is variable. Histologic hyperplasia, prostate enlargement, symptom severity, and bladder outlet obstruction (BOO) do not always occur to the same degree, and prostate size alone does not reliably reflect the

functional burden of disease [1,2]. Current evaluation therefore combines symptom assessment with prostate morphology, post-void residual urine, uroflowmetry, and, when uncertainty remains, pressure-flow urodynamics. Chronic outlet resistance may lead to compensatory detrusor hypertrophy and structural remodeling of the urinary bladder. For this reason, ultrasonographic measurements of bladder wall thickness (BWT) and detrusor wall thickness (DWT) have been studied as noninvasive indicators of the bladder response to obstruction. Earlier studies reported thicker bladder walls in men with LUTS and benign prostatic enlargement than in asymptomatic controls, and several studies found meaningful associations between DWT/BWT and urodynamically confirmed BOO [3-6]. More recent meta-analyses have also shown promising diagnostic performance for detrusor wall measurements, while highlighting differences in measurement technique, bladder filling volume, diagnostic thresholds, and reference standards [7,8]. BWT is attractive in clinical practice because it can be measured during routine transabdominal ultrasonography without radiation, catheterization, or major additional cost. This can be particularly useful where formal urodynamic testing is not readily available. However, BWT is affected by bladder filling, age, measurement site, detrusor physiology, and the duration of obstruction. It should therefore not be considered equivalent to urodynamic evidence of BOO. Current European guidance recognizes the association between bladder wall thickness and obstruction but does not recommend BWT/DWT as a stand-alone replacement for pressure-flow studies because measurement methods and diagnostic thresholds remain insufficiently standardized [1]. In the present study, BWT was examined in relation to several aspects of BPH, including symptom severity measured by the International Prostate Symptom Score (IPSS), duration of clinically recognized BPH, prostate size, and sonographic BPH grade. The main clinical question was whether routinely measured transabdominal BWT could serve as an adjunctive marker of symptom burden and chronic lower urinary tract remodeling.

2. MATERIALS AND METHODS

2.1 Study design and setting

A cross-sectional analytical study was carried out in the Radiology Department of Services Hospital, Lahore, Pakistan. The study covered 12 months in total, including 9 months of data collection. Reporting followed the principles of the STROBE statement for observational studies [18].

2.2 Participants and sampling

A total of 98 men with diagnosed BPH were enrolled through non-probability purposive sampling. Eligible participants were 40-98 years old and had clinical features consistent with symptomatic BPH. Patients with urethral stricture, previous prostate surgery, neurogenic bladder, or chronic kidney disease were excluded. The sample size of 98 was determined in advance using previously published data, with 80% statistical power, a 95% confidence level, and a 5% margin of error [15].

2.3 Ultrasonography protocol

Ultrasonography was performed with a Toshiba Aplio 200 system using a 3-5 MHz curvilinear transducer. Examinations were carried out with the urinary bladder partially filled to provide an acoustic window. The probe was angled approximately 30 degrees caudally, and gentle compression was applied when necessary to prevent bladder-base shadowing from obscuring the inferior prostate. Prostate width was measured in the transverse plane. The transducer was then rotated by approximately 90 degrees to obtain the maximum anteroposterior height and craniocaudal length in the longitudinal plane. Prostate size was estimated with the ellipsoid equation: width x height x length x 0.52. In the study records, prostate size was reported in grams, following the conventional approximation of prostate volume to weight.

Urinary bladder wall thickness was measured transabdominally in millimeters. Prostate size, post-void residual volume, sonographic BPH grade, PSA, IPSS, and duration of BPH were also recorded. The study records did not specify a fixed bladder volume at the time of BWT measurement or a single standardized bladder-

wall measurement site. This limitation is discussed later in the manuscript.

2.4 Clinical variables and definitions

IPSS severity was classified using the standard thresholds of mild (0-7), moderate (8-19), and severe (20-35) symptoms [16]. Sonographic BPH was categorized by estimated prostate size as grade I (26-30 g), grade II (>30-50 g), grade III (>50-85 g), and grade IV (>85 g). Duration of BPH was recorded in years. The primary outcomes were the associations of BWT with IPSS symptom category and BPH duration. Associations with prostate size and BPH grade were treated as secondary exploratory outcomes.

2.5 Statistical analysis

Data were analyzed using MedCalc statistical software. Quantitative variables were summarized by mean and standard deviation when appropriate, while categorical variables were reported as frequencies and percentages. Continuous associations were assessed with Pearson or Spearman correlation according to

the analysis plan. Because the distribution of BWT differed across IPSS categories, the three symptom groups were compared with the Kruskal-Wallis test, followed by Conover post-hoc comparisons. Univariable least-squares regression was used to examine the relationship of BWT with prostate size and BPH grade. Regression residuals were assessed for normality using the Shapiro-Wilk test. A two-sided p value <0.05 was considered statistically significant. Because residual normality was rejected in both regression models, the linear regression findings were interpreted as exploratory effect estimates rather than definitive predictive models.

3. RESULTS

3.1 Participant characteristics

The study included 98 men. Their mean age was 64.84 ± 12.92 years, with an age range of 43-98 years. According to IPSS, 71 (72.4%) had mild symptoms, 21 (21.4%) had moderate symptoms, and 6 (6.1%) had severe symptoms.

Table 1. Participant characteristics and IPSS distribution

Characteristic	Overall / category	Value	Notes
Sample size	All participants	98	Cross-sectional cohort
Age, years	Mean $\pm$ SD	64.837 ± 12.918	Range 43-98
IPSS category	Mild	71 (72.4%)	IPSS 0-7
IPSS category	Moderate	21 (21.4%)	IPSS 8-19
IPSS category	Severe	6 (6.1%)	IPSS 20-35

3.2 Age and prostate size

Age had a statistically significant positive correlation with prostate size ($r=0.3547$, 95% CI 0.1682-0.5168; $p=0.0003$). The association was modest, showing that prostate size tended to increase with age, although age explained only a limited amount of the variation between individuals.

3.3 Bladder wall thickness across IPSS symptom categories

BWT differed significantly among the three IPSS categories (Kruskal-Wallis corrected

$H=25.1852$, $df=2$; $p=0.000003$). Median BWT was 5.0 mm in the mild group, 6.5 mm in the moderate group, and 6.0 mm in the severe group. Conover post-hoc analysis showed that the mild group differed significantly from both the moderate and severe groups ($p<0.05$). Because the severe group was small ($n=6$) and had a wide spread of values, the findings support overall group differences in BWT but do not show a strictly progressive increase from moderate to severe symptoms.

Table 2. Bladder wall thickness by IPSS symptom category

IPSS category	n	Minimum	25th percentile	Median	75th percentile	Maximum
Mild	71	3.0	4.0	5.0	5.65	7.4
Moderate	21	4.4	6.175	6.5	7.0	7.2
Severe	6	4.0	4.6	6.0	8.9	9.1

Bladder Wall Thickness Across IPSS Severity Categories

Kruskal-Wallis H = 25.19, df = 2, p < 0.001

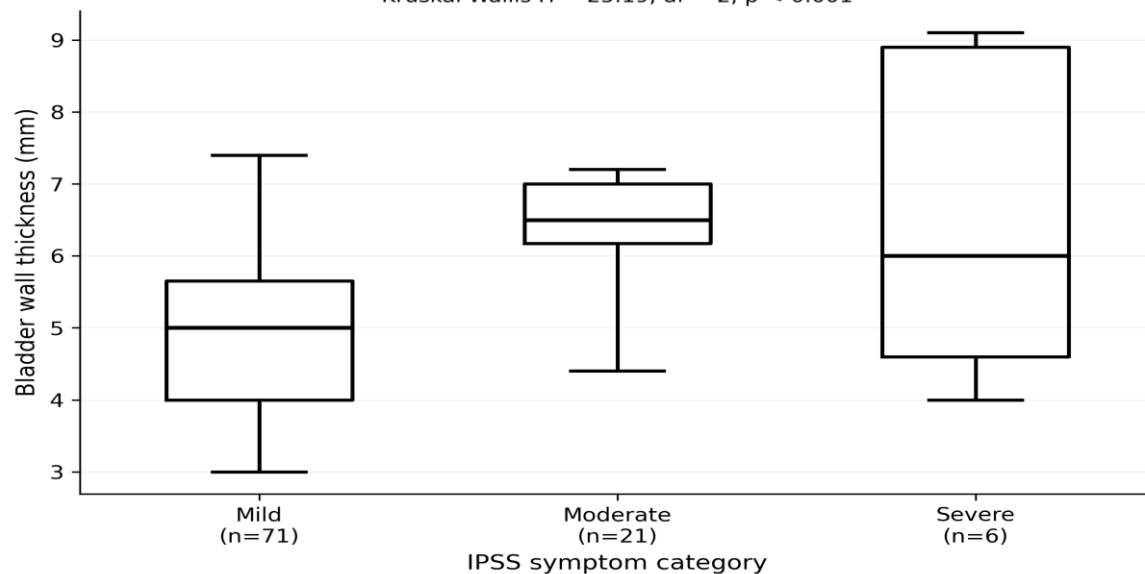


Figure 1. Bladder wall thickness according to IPSS severity category. The box-and-whisker plot was reconstructed from the five-number summaries reported in the thesis. Boxes show the interquartile range, center lines indicate the median, and whiskers represent the reported minimum and maximum values. The severe group was small (n=6) and therefore had a wide interquartile range.

3.4 Association of BPH Duration, Prostate Size, BPH Grade, and Bladder Wall Thickness

BWT was positively correlated with the duration of BPH ($r=0.3009$, 95% CI 0.1090-0.4712; $p=0.0026$). Although statistically significant, the association was modest. This suggests that BWT may reflect one aspect of chronic bladder remodeling rather than serving as a direct measure of symptom duration. In univariable least-squares regression, prostate size was positively associated with BWT. The fitted equation was $BWT = 4.5410 + 0.01357 \times \text{prostate size}$, with a slope of 0.01357 mm per gram (95% CI 0.004321-0.02283; $p=0.0045$) and $R^2=0.08115$. Prostate size therefore

explained approximately 8.1% of the variation in BWT. The Shapiro-Wilk test showed non-normal regression residuals ($W=0.9684$; $p=0.0185$), so the linear model should be interpreted with caution. BPH grade also had a positive exploratory linear association with BWT. The fitted equation was $BWT = 3.4072 + 0.7443 \times \text{BPH grade}$, with a slope of 0.7443 mm per grade (95% CI 0.3594-1.1293; $p=0.0002$) and $R^2=0.1330$. The model explained approximately 13.3% of the variation in BWT. Residual normality was again rejected ($W=0.9716$; $p=0.0323$). Because BPH grade is an ordinal variable, this finding is better interpreted as evidence of a positive trend than as a validated linear prediction rule.

Table 3. Summary of association and regression analyses

Analysis	Outcome	Predictor / grouping	Effect estimate	95% CI / model fit	p value
Correlation	Prostate size	Age	$r=0.3547$	0.1682 to 0.5168	0.0003
Kruskal-Wallis	BWT	IPSS category	$H=25.1852$	$df=2$	0.000003
Correlation	BWT	BPH duration	$r=0.3009$	0.1090 to 0.4712	0.0026
Linear regression	BWT	Prostate size	slope=0.01357 mm/g	$R^2=0.08115$; slope CI 0.004321-0.02283	0.0045
Linear trend regression	BWT	BPH grade	slope=0.7443 mm/grade	$R^2=0.1330$; slope CI 0.3594-1.1293	0.0002

BWT = bladder wall thickness; CI = confidence interval; R^2 = coefficient of determination. Regression residuals were non-normal for both prostate size ($p=0.0185$) and BPH grade ($p=0.0323$).

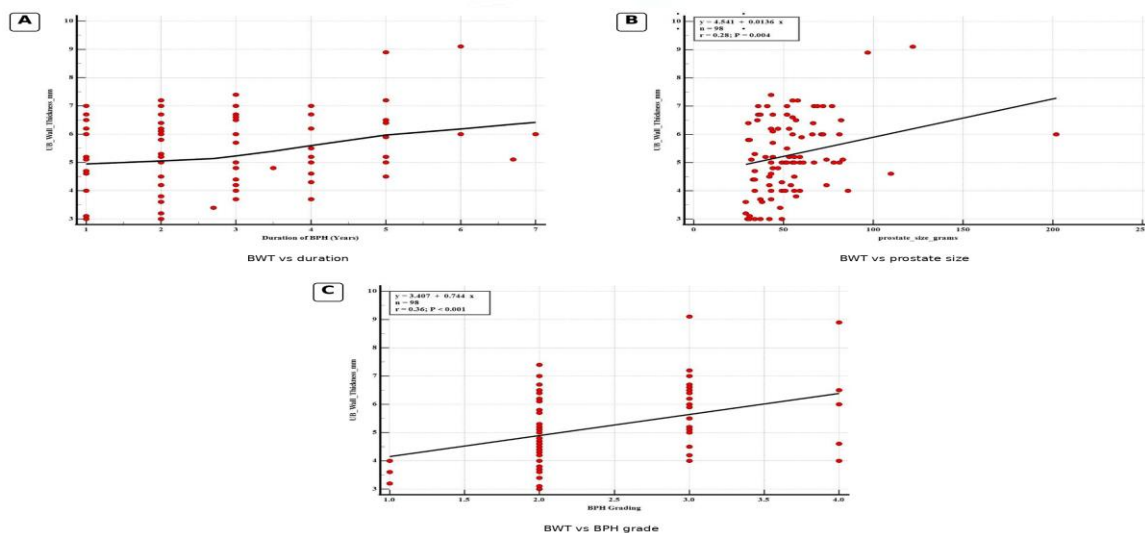


Figure 2. Scatterplots showing the main continuous and ordinal associations. (A) BWT versus duration of BPH. (B) BWT versus prostate size. (C) BWT versus sonographic BPH grade. The original MedCalc plots were taken from the thesis and combined into a single figure without changing the underlying data display.

3.5 Representative ultrasound appearances

Representative transabdominal ultrasound images from the study archive show the range of prostate size, BPH grade, bladder wall thickness, and symptom burden seen among

individual participants. The image also show that prostate size and BWT do not have a simple one-to-one relationship, which is consistent with the modest R^2 values, observed in the regression analyses.

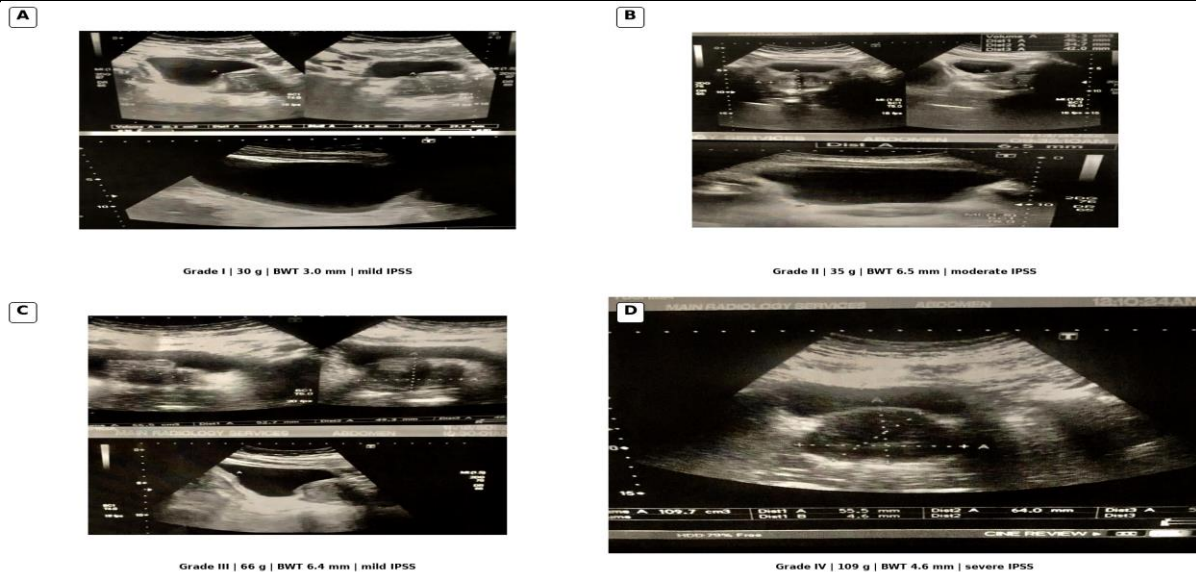


Figure 3. Representative transabdominal ultrasound images from the thesis study archive. (A) Grade I BPH, estimated prostate size 30 g, BWT 3.0 mm, mild IPSS. (B) Grade II BPH, 35 g, BWT 6.5 mm, moderate IPSS. (C) Grade III BPH, 66 g, BWT 6.4 mm, mild IPSS. (D) Grade IV BPH, 109 g, BWT 4.6 mm, severe IPSS. These examples demonstrate variability between individual cases and should not be interpreted as a stepwise severity sequence.

4. DISCUSSION

This study showed that transabdominal ultrasound-measured BWT was associated with several measures of BPH burden. BWT differed across IPSS categories, correlated with BPH duration, and was positively associated with prostate size and sonographic BPH grade. The effect sizes were modest: prostate size explained 8.1% of BWT variation and BPH grade explained 13.3%. BWT may therefore be useful as an adjunctive marker of lower urinary tract remodeling, but not as a direct measure of prostate enlargement or symptom severity. Previous studies have reported mixed findings. Anwar et al. found a strong positive association between BWT and IPSS in men with BPH [15], whereas Aisuodionoe-Shadrach et al. reported weak, non-significant correlations between IPSS and BWT measured with a full or empty bladder [10]. Yilmaz et al. also found no significant correlation between BWT and IPSS, although symptom duration was longer in patients with thicker bladder walls [9]. In our cohort, the Kruskal-Wallis analysis showed an overall difference among symptom groups, with the mild group differing from both the moderate and severe groups. Median BWT was 6.5 mm in the moderate group and 6.0 mm in the severe group, while the severe subgroup

included only six patients. These findings support higher BWT beyond the mild symptom category but not a strictly stepwise increase across all three IPSS groups. The association between BWT and BPH duration is biologically plausible because persistent outlet resistance increases detrusor workload and may lead to smooth-muscle hypertrophy, altered collagen deposition, and changes in bladder compliance. Earlier ultrasound studies found thicker detrusor walls in obstructed than unobstructed men and showed that DWT could help distinguish BOO under standardized filling conditions [4,5]. The correlation with duration in our study was modest ($r=0.3009$), but it is consistent with BWT reflecting cumulative lower urinary tract loading and agrees with the findings of Yilmaz et al. [9]. The weak relationship between prostate size and BWT is also important because BPH-related obstruction is influenced by more than gland size alone. Smooth-muscle tone, urethral geometry, intravesical prostatic protrusion, bladder contractility, and individual compensatory responses can all affect the clinical picture. Multimodal sonomorphologic studies suggest that BWT/DWT, intravesical prostatic protrusion, prostate size, and ultrasound-estimated bladder weight may provide

complementary information [11-14]. Our R² value of 0.08115 for prostate size shows that most BWT variation was related to factors other than gland size, supporting the need to avoid equating prostate enlargement with the physiological degree of obstruction. BPH grade also showed a positive trend, but this result should be interpreted cautiously. Grade was entered numerically in the least-squares regression despite being ordinal, and the residuals were non-normal. The significant slope therefore indicates an ordered association rather than a precise linear dose-response. Future patient-level analyses should consider a non-parametric trend test, ordinal-group comparison, or robust regression, with adjustment for age, bladder filling volume, prostate size, PVR, and other relevant covariates. Clinically, BWT may serve as a low-cost additional measure during routine transabdominal assessment. Meta-analyses have reported useful diagnostic performance for detrusor wall measurements in BOO, particularly when technique and bladder volume are standardized [7,8]. Current EAU guidance, however, notes substantial variation in protocols and thresholds and advises against replacing urodynamic pressure-flow studies with noninvasive wall-thickness measurements when definitive confirmation of obstruction is required [1]. Our findings therefore support BWT as a marker of chronic remodeling, but not as a replacement for urodynamics. The study has several strengths, including the use of a single-center protocol and ultrasound platform, a broad adult age range, evaluation of BWT against several clinically relevant measures, and inclusion of original sonographic examples. The association between BPH duration and BWT is particularly relevant because chronicity is not captured by prostate size alone. Important limitations include the cross-sectional design, purposive sampling from a single hospital, and the small severe IPSS subgroup. The study records also did not specify a fixed bladder filling volume, exact BWT measurement site, repeated measurements, or interobserver reliability. Pressure-flow urodynamics was not used as a reference standard for BOO, so the findings describe associations with clinical BPH burden

rather than diagnostic accuracy for obstruction. Both regression models had non-normal residuals, and BPH grade was analyzed as a numeric predictor despite being ordinal. Finally, the analyses were univariable and cannot determine whether BWT is independently associated with disease severity after adjustment for age, prostate size, PVR, or other confounders.

5. CONCLUSION

The transabdominal ultrasound-measured bladder wall thickness was significantly associated with IPSS symptom category, duration of BPH, prostate size, and sonographic BPH grade. The association with symptom duration, together with the higher BWT seen beyond the mild IPSS category, is consistent with chronic detrusor remodeling. However, substantial overlap between individuals, modest effect sizes, non-standardized bladder filling, and the lack of urodynamic confirmation limit the value of BWT as a stand-alone diagnostic marker. In routine practice, BWT may be most useful as an additional measure alongside symptom scoring, prostate morphology, post-void residual assessment, uroflowmetry, and clinical judgment, particularly when a rapid, noninvasive assessment is needed.

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