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Dynamic Evaluation of Urinary Bladder Wall Thickening in Sudanese Patients with Recurrent Urinary Tract Infections Using Ultrasonography: A Comparative Analysis before and after Voiding

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Abstract | **Original Research Article**

Background: Recurrent urinary tract infections (UTIs) can lead to chronic inflammation and morphological changes in the bladder, such as a thickened wall. Ultrasonography is a non-invasive tool to assess these changes. ***Objective:*** This study aimed to evaluate the dynamic changes in bladder wall thickness (BWT) before and after voiding in Sudanese patients with a history of recurrent UTIs using transabdominal ultrasonography. ***Methods:*** This cross-sectional, descriptive study included 92 adult participants (54.3% female, 45.7% male) with a mean age of 49.5 ± 16.1 years, all with a history of recurrent UTIs. Transabdominal ultrasound was performed to measure anterior and posterior BWT, pre-void bladder volume (PBV), and post-void residual volume (PVR). Bladder emptying efficiency (BEE) was calculated. Statistical analysis was conducted using the Wilcoxon signed-rank test, Pearson correlation, and chi-square tests. ***Results:*** The mean anterior BWT increased significantly from 3.7 ± 1.2 mm pre-voiding to 5.1 ± 1.2 mm post-voiding. Similarly, posterior BWT increased significantly after voiding. The Wilcoxon signed-rank test confirmed that these changes in both anterior and posterior wall thickness were statistically significant ($Z = -8.023$ and $Z = -6.598$, respectively; $p < .001$ for both). A significant negative correlation was observed between age and BEE ($r = -0.228$, $p = 0.029$) ***Conclusion:*** The study demonstrates a significant increase in bladder wall thickness after voiding in patients with recurrent UTIs. It also highlights that bladder emptying efficiency is influenced by age and gender in this population. Post-void BWT measurement may serve as a valuable sonographic marker for assessing bladder changes related to chronic infection.

Keywords: Recurrent UTIs, Bladder wall thickness (BWT), Ultrasonography, Voiding, Chronic inflammation.

INTRODUCTION

Urinary tract infections (UTIs) represent a major global health issue, affecting approximately 150 million people annually, making them one of the most common urologic problems worldwide [1] These infections, which are more prevalent in females than males, typically result from uropathogenic bacteria ascending the urethra and colonizing the bladder, leading to an inflammatory response known as cystitis [2]. The pathogenesis involves bacterial virulence factors that facilitate adherence and colonization [3]

Recurrent UTI, often defined as three or more episodes within 12 months, is typically caused by reinfection rather than the persistence of the same bacterial strain [3]. Chronic inflammation from recurrent UTIs can induce detrusor hypertrophy, leading to a measurable thickening of the bladder wall [2,3] whichis associated with healthcare-associated infections (HAIs) and various other underlying conditions, making its early diagnosis crucial.

Transabdominal ultrasonography is a non-invasive, accessible, and reliable method for assessing bladder morphology, including bladder wall thickness (BWT) [4]. While BWT changes are well-documented in conditions like bladder outlet obstruction, the specific dynamic changes occurring before and after voiding in adult patients with recurrent UTIs are less characterized. Understanding these dynamic patterns is clinically important for managing this patient population. Therefore, this study aimed to evaluate the dynamic

changes in anterior and posterior BWT, measured by transabdominal ultrasonography before and after voiding, in Sudanese adult patients with a history of recurrent UTIs.

Materials and Methods

Study Design and Participants

This cross-sectional, descriptive study was conducted at Ibn Sina Hospital between June and September 2021. An initial 99 patients were randomly selected, from which seven withdrew, resulting in a final cohort of 92 participants. The primary inclusion criterion was a history of recurrent UTIs in patients aged 18 to 80 years. Patients with known confounding conditions such as active bladder malignancy, recent urological surgery, or neurogenic bladder were excluded.

Ultrasound Protocol

A Canon Xario-100 ultrasound machine with a 3.5 MHz curvilinear transabdominal transducer was used for all examinations. Patients were instructed to drink approximately two liters of water to ensure adequate bladder filling for the initial scan. The patient was examined in the supine position.

Measurements

Bladder Volume: Pre-voiding bladder volume (V1) was measured. Patients then voided completely, and the post-voiding residual volume (V2) was measured immediately upon their return. Volume was calculated using the standard ellipsoid formula:

$$\text{Volume}=0.72\times\text{Length}\times\text{Width}\times\text{Height}$$

Bladder Wall Thickness (BWT): The thickness of the anterior and posterior bladder walls was measured in millimeters (mm) on transverse and longitudinal images, both before (pre-void) and after (post-void) micturition.

Bladder Emptying Efficiency (BEE): BEE was calculated to assess voiding function using the formula:

$$\text{BEE}(\%)= (V1-V2)/V1 \times 100\%$$

Data Analysis

Data were analyzed using SPSS V.25 statistical software. Descriptive statistics (mean, standard deviation) were calculated for demographic and sonographic variables. The Wilcoxon signed-rank test was used to compare pre- and post-voiding BWT. Pearson correlation was used to assess the relationship between continuous variables like age and bladder parameters. The chi-square test was used to evaluate associations between categorical variables, such as gender, and bladder parameters. A p-value of < 0.05 was considered statistically significant.

Results

Participant Characteristics

The study comprised 92 participants, including 50 females (54.3%) and 42 males (45.7%). The mean age of the cohort was 49.5 ± 16.1 years. Table (1).

Descriptive Bladder Measurements

The overall mean pre-void bladder volume was 169.1 ± 83.7 mL, and the mean post-void residual volume (PVR) was 23.1 ± 41.5 mL. The mean bladder emptying efficiency (BEE) for the group was 84.9% ± 18.8%. The mean pre-void anterior BWT was 3.7 ± 1.2 mm, and the mean post-void anterior BWT was 5.1 ± 1.2 mm. For the posterior wall, the mean thickness was 5.53 ± 1.0 mm pre-voiding and 6.24 ± 1.23 mm post-voiding. Table (1)

Table 1: Descriptive analysis of Demographic Data

Gender	N	AGE	PVR	PBV m3	BWT pre	BWT post	BEE%	BEE score frequency	
								>90 N(f)	<90 N(f)
Female	50	41.74±14.2	25.3±53.4	170.5±95.2	3.8±1.2	5.08±1.2	86.3±17.2	23(46%)	27(54%)
Male	42	58.64±13.05	20.5±20.2	167.4±68.7	3.7±1.1	5.16±1.3	83.3±20.6	21(50%)	21(50%)
All	92	49.5±16.1	23.1±41.5	169.1±83.7	3.7±1.2	5.1±1.2	84.96±18.8	44(47.8%)	48(52.2%)

Post-void Anterior wall thickness(BWT pre)
Pre-void anterior wall thickness(BWT post)
Post void residual volume (PVR)
Bladder volume (PBV)
bladder emptying efficiency (BEE)
Bladder volume (BV)

Dynamic Changes in Bladder Wall Thickness

A significant increase in BWT was observed after voiding in a normal manner. For the anterior wall, post-void thickness was greater than pre-void thickness in 86 of the 92 cases. For the posterior wall, post-void thickness was greater in 84 cases. The Wilcoxon signed-rank test confirmed that the increase in thickness from pre- to post-voiding was highly significant for both the anterior wall ($Z = -8.023$, $p < .001$) and the posterior wall ($Z = -6.598$, $p < .001$).

Table 2: Wilcoxon Signed-Rank Test Results for Bladder Wall Thickness (Pre-void vs. Post-void)

Comparison	Direction	N	Mean Rank	Sum of Ranks	Z	P value
B Anterior Wall (Post-Pre)	Increased (Post > Pre)	86	46.98	4040.50	-8.023	.000
	Decreased (Post < Pre)	4	13.63	54.50		
	No Change	2	—	—		
B Posterior Wall (Post - Pre)	Increased (Post > Pre)	84	45.62	3832.00	-6.598	.000
	Decreased (Post < Pre)	8	55.75	446.00		
	No Change	0	—			

Effect of Age and Gender on Bladder Parameters Correlation and association analyses revealed the influence of demographic factors on bladder function (Table 3): Age: Age showed a negligible correlation with BWT (r = 0.031, p = 0.771) and a weak, non-significant positive correlation with urine residual volume (r = 0.138, p = 0.190). However, there was a statistically significant negative correlation between age and Bladder Emptying Efficiency (r = -0.228, p = 0.029), indicating that BEE tended to decrease in older participants. Gender showed no significant association with BWT or PVR. However, there was a significant association between gender and Bladder Emptying Efficiency ($\chi 2$ = 0.472, p = 0.017) and Bladder Volume ($\chi 2$ = 0.451, p = 0.008), Table 3. In this cohort, females had a slightly higher mean BEE (86.3%) compared to males (83.3%) Table 4.

Table 3: Effect of age and gender on bladder wall thickness (BWT), Urine residual volume, bladder emptying efficiency (BEE) and Bladder volume (BV)

	BWT	Urine residual volume	BEE	Bladder VOLUME
Age	r = .031 p = .771	r = .138 p = .190	r = -.228* p = .029	R =.118 P =.264
Gender	x^2 =.422 P = 165	x^2 = .472** P = .017	x^2 = .451** P =.008	X^2 = .457** P =.009

Table 4: Descriptive analysis of BEE Grouping by Gender

Gender		N	Minimum	Maximum	Mean	Std. Deviation
Female	Bladder emptying efficiency	50	3.78	99.16	86.3323	17.27007
Male	Bladder emptying efficiency	42	17.55	99.20	83.3385	20.66471

Table 5 presents the distribution of BEE scores by gender. The majority of participants in both genders scored above 75, with 90% of males (45 out of 50) and 80.95% of females (34 out of 42) falling into this highest range. A small proportion of participants scored in the lower ranges: 4.35% had scores below 25, and 2.17% scored between 25 and 50. Only 7.61% of participants had scores in the 50–75 range. Overall, 85.87% of the total sample scored above 75, indicating a strong performance across the cohort.However, a higher proportion of males had a BEE greater than 90% (50%) compared to females (46%) Table 1.

Table 5: BEE Group Distribution by Gender and Score Range

BEE Group	Male (M)	% of M (n=50)	Female (F)	% of F (n=42)	Total	% of Total (n=92)
<25	1	2.00%	3	7.14%	4	4.35%
25–50	2	4.00%	0	0.00%	2	2.17%
50–75	2	4.00%	5	11.90%	7	7.61%
>75	45	90.00%	34	80.95%	79	85.87%
Total	**50**	**100.00%**	**42**	**100.00%**	**92**	**100.00%**

The highest efficiency scores are observed in the youngest group (less than 25), with minimal variability and few outliers. As age increases, the variability in efficiency widens, particularly in the 56–65 and "more than 66" age groups. These older groups show lower median efficiency values and more pronounced outliers, indicating a decline in bladder emptying efficiency with age. Notably, the 46–55 and 56–65 groups include several extreme low-efficiency cases, emphasizing age-related deterioration in bladder function. (Figure 1)

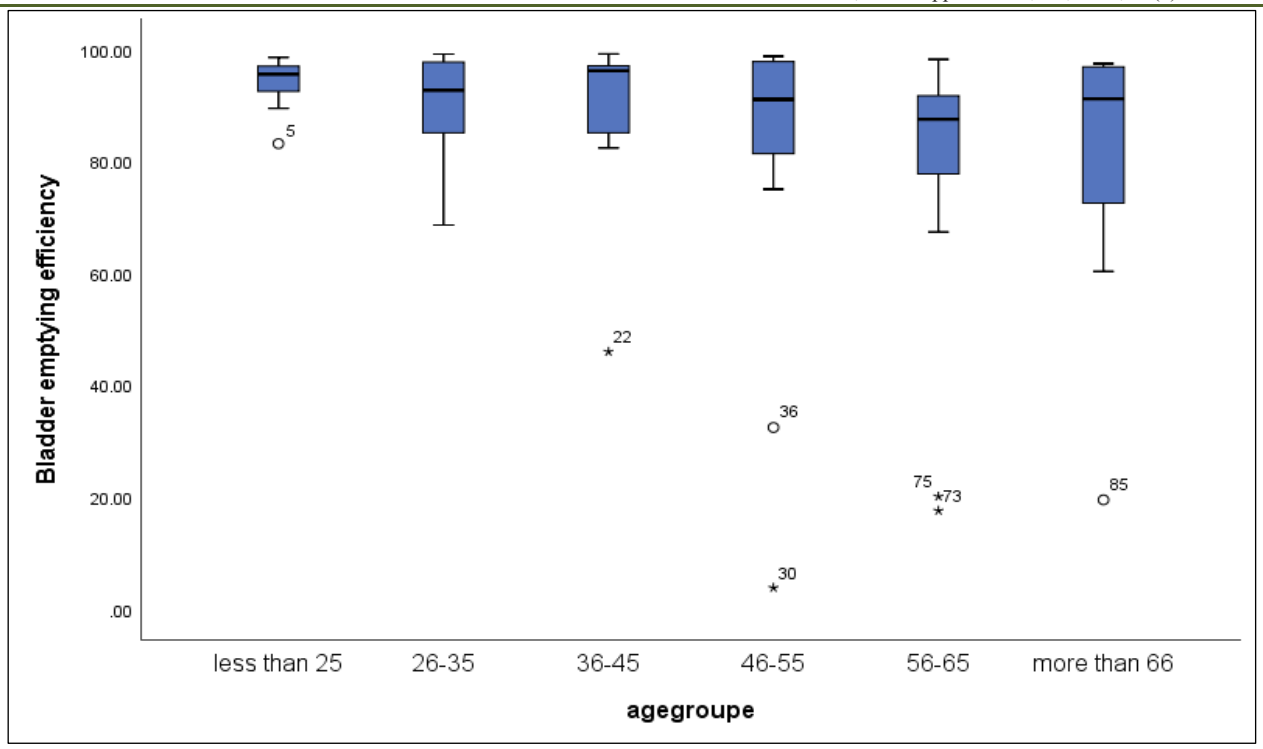

Figure 1: Boxplot of Bladder Emptying Efficiency Across Age Groups

DISCUSSION

This study investigated the dynamic sonographic changes of the bladder wall in patients with recurrent UTIs, revealing several key findings regarding BWT, age, and gender.

The primary finding was the significant increase in both anterior and posterior BWT after micturition. This phenomenon is physiologically expected, as the bladder wall contracts and becomes thicker in an empty state compared to a distended, full state. However, the absolute thickness, particularly post-voiding, is of clinical interest. A BWT greater than 3 mm in a moderately full bladder or greater than 5 mm in an empty bladder is often considered thickened [5]. Our study found a mean post-void anterior BWT of 5.1 mm and posterior BWT of 6.24 mm, values that are at or above the upper limit of normal, suggesting underlying pathology such as the detrusor hypertrophy expected with chronic inflammation from recurrent UTIs [2,5]. The mean pre-void anterior BWT of 3.7 mm in our cohort is also noteworthy, as it suggests thickening even in a distended state. For comparison, a study on men with benign prostatic hyperplasia (BPH) reported a mean BWT of 4.4 mm, which is also considered a cause of detrusor hypertrophy [6].Early applications of ultrasound in urology included techniques like the ultrasound cystodynamogram, which provided initial insights into bladder function [7]. Blatt et al [8]correlated bladder wall thickness with urodynamic diagnoses and observed a slight difference between males and females, with reported values ranging from 1.1 to 4.5 mm across different urodynamic conditions. Our study provides comparable data in a Sudanese population specifically focusing on patients with recurrent UTIs, allowing for potential cross-population comparisons.

Elevated post-void residual urine is a well-established risk factor for urinary tract infections [9,10], potentially creating a vicious cycle of infection and bladder wall changes. May *et al.,*[9] found significantly higher post-void residual urine volumes in patients with UTIs, underscoring the importance of effective bladder emptying in preventing these infections.

Our analysis showed a significant negative correlation between age and BEE ($r = -0.228$, $p = 0.029$). This finding is consistent with existing literature, which indicates that voiding function can decline with age due to factors like decreased detrusor contractility and, in men, increased outlet resistance from prostatic enlargement [4,11].

The study also identified significant gender-based differences in BEE and bladder volume. While females had a slightly higher mean BEE, a detailed look at the efficiency groupings showed that a larger proportion of men achieved over 90% efficiency. Bladder emptying is a complex process, and gender differences can be influenced by anatomical variations and different pathologies affecting the lower urinary tract [12]. The findings in our specific cohort of recurrent UTI patients warrant further investigation to understand the underlying reasons for these gender-specific patterns.

Comparing our findings with studies from other populations and urological conditions can provide valuable context. Saleh *et al.,* [13] reported increased bladder detrusor thickness in Nigerian adults with benign prostatic hyperplasia, suggesting a link between bladder wall thickening and outflow obstruction[13]. While our study focuses on recurrent UTIs, similarities or differences in the observed thickness changes could provide insights into the underlying pathophysiological mechanisms. Additionally, Shin *et al.,*[14]provided sonographic evaluations of bladder wall thickness in women with lower urinary tract dysfunction, a condition frequently associated with UTIs[14]. Comparing our results, particularly in female Sudanese patients with recurrent UTIs, to the findings of Shin *et al.,* could reveal potential similarities or differences in bladder wall response to infection and dysfunction across different populations.

Limitations and Future Directions

This study has some limitations. Its cross-sectional design prevents the establishment of causality or tracking of changes over time. Furthermore, the absence of a healthy control group makes it difficult to definitively attribute the observed BWT values solely to recurrent UTIs, although the values are suggestive of pathology when compared to established norms. The study was also conducted on a specific Sudanese population, which may limit the generalizability of the findings. Future longitudinal research that includes a control group would be beneficial to confirm these results and explore the prognostic value of dynamic BWT changes.

CONCLUSION

In conclusion, this study demonstrates that in patients with a history of recurrent UTIs, the bladder wall undergoes significant thickening after voiding. The absolute post-void BWT values observed are indicative of potential underlying pathology consistent with chronic inflammation. Advancing age was associated with reduced bladder emptying efficiency. These findings underscore the utility of dynamic, non-invasive ultrasonography in the clinical evaluation of patients with recurrent bladder infections.

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