Ultrasound Estimated Bladder Weight in Asymptomatic Adult Females

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Purpose: To estimate the bladder weight by automated ultrasound method (BladderScan BVM 9500) in adult females without lower urinary tract symptoms and to assess both the intra-observer and interobserver reproducibility of this method.

Materials and Methods: Healthy volunteers were recruited in King Khalid University Hospital from hospital staff and patients attending the gynecological clinic over a period of six months. All women were screened for any lower urinary tract symptoms using a validated short version of Urinary Distress Inventory questionnaire. BladderScan BVM 9500 device (Diagnostic Ultrasound, Bothell, WA) was used to measure bladder wall thickness, bladder volume, and calculated bladder weight.

Results: Eighty-five women were included in the study. The mean age was 37.5 years (± 11.1). Mean bladder wall thickness (BWT) was 1.68 mm (95% confidence interval: 1.61 to 1.75) and the mean ultrasound-estimated bladder weight (UEBW) was 32.25 g (95% confidence interval: 31.7 to 32.8). The UEBW intra-observer (ICC: 0.81) and interobserver (ICC: 0.8) reproducibility were excellent while intra-observer (ICC: 0.55) and interobserver (ICC: 0.6) reproducibility for BWT were moderate. No correlation was found between UEBW and age, height, body weight, or bladder volume.

Conclusion: The estimated bladder weight by automated ultrasound device in asymptomatic adult females yields reproducible measurements and can be used as a reference for future understanding of the changes in bladder weight related to different types of urinary incontinence or voiding disorders.

Keywords: urinary bladder, lower urinary tract symptoms, female

INTRODUCTION

Lower urinary tract symptoms (LUTS), such as urinary incontinence or voiding disorders, affect large percentage of women and can cause significant burden to affected individuals.[1] Women who suffer from LUTS often need to undergo numerous investigations to obtain a diagnosis and initiate treatment. Urodynamic studies are commonly used tests in the investigation of women with LUTS. However, they are generally invasive, time-consuming, and inconvenient to most patients, and may cause urinary tract infection.[2]

In the past decade, an increased interest in the use of ultrasonic evaluation of the bladder thickness and weight in individuals with LUTS has raised mainly because it is a quick, safe, non-invasive, easy to use, painless, and well-accepted method by patients.[3,4]

Nonetheless, a study on cadaver bladders showed a statistically significant relationship between the bladder weight and ultrasonic evaluation of the bladder weight (UEBW).[5]

However, to date, such a method has not been well-adopted into clinical practice, mainly due to the lack of normal reference values and the difficulty in comparing results between published studies.[6] Recently, the BladderScan BVM 9500 device (Diagnostic Ultrasound, Bothell, WA) has been developed. The device uses three-dimensional (3-D) ultrasound as opposed to the 2-D ultrasound originally used to calculate bladder weight. Furthermore, the device calculates the surface area of the bladder rather than assuming the bladder as a sphere. A study on the validity and reproducibility of the device measurement for bladder wall thickness (BWT) and estimated bladder weight was done in comparison with traditional approach using manual measurement by 2-D ultrasound and concluded that the BladderScan BVM 9500 device can accurately and consistently assess the bladder weight.[7]

Since the BWT measurement is affected by filled volume, it has to be at a specific bladder capacity, which limits its use in everyday practice. Therefore, calculated UEBW was introduced by Kojima to resolve this problem by overcoming the BWT and age. This problem was overcome by BladderScan 9500 BVM device. Chalana and colleagues found that 3-D ultrasound estimation of bladder weight is consistent and reproducible.[7] An additional benefit of the BladderScan 9500 BVM device is that the UEBW is measured over a range of bladder volumes; thereby, avoiding unnecessary catheterization to fill up the patient to a fixed volume.[7] Bright and associates measured the UEBW and BWT using the BladderScan 9500 BVM in men with presumably normal bladder function, which were found to be 33 g and 2.1 mm, respectively.[8]

Several studies have used ultrasonography to assess bladder weight in relation to different types of urinary incontinence and LUTS; however, to date, there are minimal data on normal range for UEBW in asymptomatic women in the literature.[3,5,9,10] Once a normal UEBW is established, then we can study whether the UEBW could correlate to LUTS or urodynamic diagnoses.

The aim of our study was to calculate the bladder weight by automated ultrasound method (BladderScan BVM 9500) in adult females without LUTS and to assess both the intra-observer and interobserver reproducibility of the BladderScan BVM 9500 device.

MATERIALS AND METHODS

After institutional ethical approval to conduct the study was obtained, healthy volunteers from different ethnic backgrounds were recruited from hospital staff and patients attending the gynecological clinic in King Khalid University Hospital over a period of six months.

All were screened using the Arabic version of Urogenital Distress Inventory short form-6 (UDI-6), which is a validated instrument commonly used in urogynecology as a screening tool for women with LUTS, prior to proceeding with ultrasound application for bladder weight estimation.[11,12] Exclusion criteria include the presence of any positive answer on the UDI-6 questionnaire, being pregnant, and declining to have the test. An informed consent explaining the study was obtained prior to participation.

Subjects' age, parity, weights, heights, menopausal status, and previous surgery were recorded, and then body mass index was calculated. Each subject underwent four measurements of the UEBW and BWT using the BladderScan 9500 BVM (Diagnostic Ultrasound, Bothell, WA) at a bladder capacity of 150 to 400 mL as per device specifications. This automated 3-D ultrasound device measures the bladder weight by initially checking the volume of the bladder content as well as aiming information for better placement of the probe with respect to the bladder direction. Thereafter, the bladder region is delineated precisely to calculate the actual surface area of the bladder as well as the BWT. Finally, the bladder weight is estimated as the product of the surface area (s), thickness (t), and bladder muscle specific gravity (p) using the following formula:

UEBW = $s \times t \times p$[7]

The measurement was done by two operators taking two recordings each, in the same setting, to evaluate the intra-observer and interobserver reproducibility of the device. The operators were blinded to each other's measurements. The scanner device uses a 3.7 MHz probe and takes 24 ultrasound planes over 5 seconds at 130 degrees. The probe is placed approximately 3 cm superior to the symphysis pubis. The scanner automatically detects misalignment of the probe and directs the user to the optimal position. Subjects whose bladder was not of sufficient capacity were rescanned in 15 to 20 minute-intervals after drinking water until a capacity of at least 150 mL was reached. Those with a capacity of > 400 mL were asked to empty around 1 cup of urine and were rescanned until a capacity of 150 to 400 mL was reached.

Two different operators performed a total of four measurements. Simple descriptive statistics were carried out as appropriate (median, mean, frequency, and percentages). The reproducibility analysis consisted of interobserver agreement and intra-observer consistency comparing different readings. Reproducibility was determined using the intraclass correlation coefficient (ICC), and approximate 95% confidence interval (CI) was calculated for the coefficient. The ICC value of 0.0 to 0.20 assumed some reliability; 0.21 to 0.40 fair; 0.41 to 0.60 moderate; 0.61 to 0.80 good; and 0.81 to 1.00 excellent reliability.[13]

RESULTS

Eighty-five women were included in the study. The mean age was 37.5 years (range, 18 to 65 years) and the mean body mass index was 27.5 kg/m^2 (Table 1). Of participants, 12.2% were post-menopausal, 17% of the women had a previous cesarean section, and none had undergone hysterectomy. Mean BWT was 1.62 mm (95% CI: 1.61 to 1.75), while the mean UEBW was 32.23 g (95% CI: 31.7 to 32.8).

The UEBW intra-observer and interobserver reproducibility were 0.8 and 0.81, respectively (Table 2; $P < .001$). While for BWT, intra-observer reproducibility was 0.55 ($P < .001$) and the interobserver reproducibility was 0.6 (Table 2; $P < .001$). The Bland-Altman plot confirmed the interobserver reproducibility for UEBW and BWT (Figures 1 and 2). The UEBW intra-observer (ICC: 0.81) and interobserver (ICC: 0.8) reproducibility were excellent. While intra-observer (ICC: 0.55) and interobserver (ICC: 0.6) reproducibility for BWT were moderate.

The multivariate regression model was used to assess characteristics affecting the UEBW. It showed that age, weight, height, and bladder volume had no significant correlation with UEBW. The sample was divided into multiple groups according to age, and there was no difference in the UEBW between different age groups.

Table 1. Association between specific sample characteristics and ultrasonic evaluation of the bladder weight.

Characteristics	Mean (± standard deviation)	Range	r	*P*
Age, y	37.5 (11.1)	18 to 65	0.02	.26
Height, cm	155.6 (6)	143 to 175	0.05	.36
Weight, kg	66.7 (14.5)	32 to 106	0.09	.06
Body mass index, kg/m^2	27.5 (5.6)	13 to 42	0.19	.10

DISCUSSION

Ultrasound imaging of the BWT and estimation of bladder weight have been introduced over a decade ago to assess the state of bladder hypertrophy secondary to outlet obstruction and detrusor overactivity, as an alternative method to invasive, expensive, and time-consuming uro-

Table 2. Reliability of BladderScan BVM 9500 for ultrasonic evaluation of the bladder weight and bladder wall thickness measurements.

		Ultrasound Estimated Bladder Weight				Bladder Wall Thickness			
		Mean (SD), g	Range	Intra-observer correlation coefficient	Interobserver correlation coefficient	Mean (SD), mm	Range	Intra-observer correlation coefficient	Interobserver correlation coefficient
Operator 1	Trial 1	32.05 (4.86)	22 to 45	0.8	0.81	1.61 (0.35)	1 to 3	0.47	0.6
	Trial 2	32.20 (4.75)	21 to 43			1.61 (0.31)	1 to 3		
Operator 2	Trial 3	32.0 (4.78)	22 to 48	0.79		1.62 (0.37)	1 to 3	0.55	
	Trial 4	32.66 (4.91)	21 to 43			1.63 (0.33)	1 to 2		

SD indicates standard deviation.

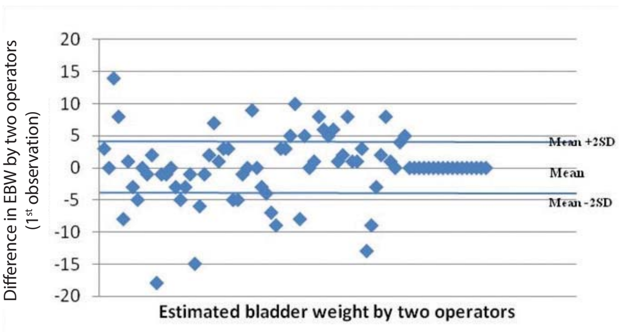

Figure 1. The Bland-Altman plot of the interobserver reproducibility for ultrasonic evaluation of the bladder weight.

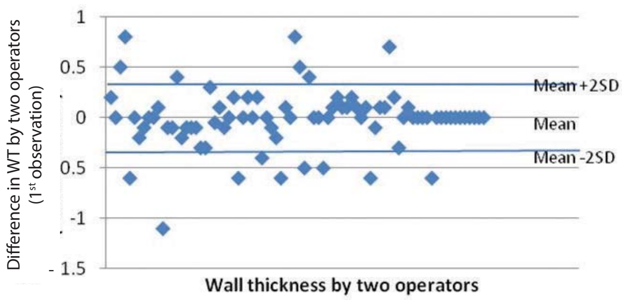

Figure 2. The Bland-Altman plot of the interobserver reproducibility for bladder wall thickness.

dynamic investigations. In a meta-analysis of diagnostic tests for bladder outlet obstruction, the authors concluded that BWT is a promising measurement that has the potential to replace urodynamic evaluation.[14]

Since BWT is affected by filling volume, its usefulness as a clinical tool becomes limited in everyday practice. Kojima and colleagues attempted to resolve this problem by calculating bladder weight. They have estimated bladder weight by measuring the BWT on ultrasound images. They concluded that UEBW can be another form for assessing bladder function beside urodynamic parameters.[5,9]

In a review article by Bright and associates, the authors demonstrated lack of data on UEBW and BWT in the healthy asymptomatic population. Such normative data are needed to understand the discrepancies in UEBW and BWT among studies on patients with LUTS.[6]

This study showed that the mean bladder weight by automated ultrasound method (BladderScan BVM 9500) in adult females without LUTS is 32.23 gm (standard deviation: 4.9) and mean BWT is 1.62 mm (standard deviation: 0.34). The use of a portable automated ultrasound device in measurement of UEBW and BWT showed highly to moderately reproducible values both in the intra-observer and interobserver measurements.

This study also found that UEBW has no correlation with age, weight, or height. We, in agreement with other such studies, did not detect an increase in bladder weight in association with increasing age in female adults.[15]

The results of this study can be a base for understanding the changes in bladder weights related to different types of urinary incontinence or voiding disorder. Further large scale studies to assess whether UEBW could be correlated to LUTS or urodynamic findings are needed, especially that the measurement techniques for bladder weight or thickness have not yet been standardized in the scientific literature.[6] Therefore, automated method for UEBW by BVM 9500 can be a reliable way to estimate bladder weight.

This study has some limitations; we did not have any subject over the age of 65 years in the study population. In addition, the device used (Bladderscan BVM 9500) has a narrow bladder volume range (150 to 400 mL) within which such measurements can be obtained. Therefore, restricts its use in patients with a small capacity bladder, such as some with overactive bladder syndrome and with large residuals secondary to chronic retention.

Future studies looking at the bladder weight in asymptomatic females should consider larger sample size with attention to the predictive diagnostic performance of the automated bladder scanner (BVM 9500), including its sensitivity, specificity, and predictive value.

CONCLUSION

The UEBW, as a non-invasive modality, might be capable of evaluating bladder hypertrophy in female patients with urinary incontinence and LUTS.

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CONFLICT OF INTEREST

None declared.

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