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Transabdominal Ultrasound Measurement of Detrusor Wall Thickness in Patients with Overactive Bladder

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Abstract

Objective: To measure the detrusor wall thickness (DWT) in patients with overactive bladder (OAB) to determine whether it can be used as a biomarker for assessment in these patients.
Materials and Methods: Transabdominal sonography of the bladder using an 8-MHz probe to measure DWT was performed in patients with OAB dry, OAB wet and healthy controls. Bladder volume was determined by the summation of the voided volume and the postvoid residual. The DWT for a bladder volume less than 250 mL was further corrected to an equivalent volume of 250 mL and then compared among subgroups of men and women.
Results: A total of 208 subjects were recruited, including 69 controls, 89 patients with OAB dry and 50 patients with OAB wet. There were 101 men and 107 women. Wide variations in the DWT were noted among the subgroups. After correction for bladder volume, DWT in the OAB dry and OAB wet groups was significantly higher in men (1.41±0.30 mm and 1.50±0.48 mm, respectively; $p<0.0001$) but not in women (1.21±0.36 mm and 1.32±0.39 mm, respectively; $p>0.05$) when compared to controls (men, 1.02±0.24 mm; women, 1.11±0.32 mm). Men with OAB dry had a significantly higher corrected DWT than women, but the corrected DWT showed no significant difference between men and women with OAB wet.
Conclusion: DWT values in patients with OAB were increased in men but not in women, suggesting a difference in the underlying pathophysiology in men with OAB. Based on our results, we do not recommend using DWT as a biomarker for assessing OAB in women. [*Tzu Chi Med J* 2009; 21(2):129–135]

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1. Introduction

Overactive bladder (OAB) is a highly prevalent bladder dysfunction with an undefined pathogenesis. OAB is usually diagnosed based on subjective symptoms. Patients with OAB present with urgency with or without urgency incontinence [1]. Although urodynamic study is frequently used to find detrusor overactivity (DO) in OAB patients, Hashim and Abrams found that 69% of men and 44% of women with urgency (OAB dry) had DO, while 90% of men and 58% of women with urgency and urgency incontinence (OAB wet) had DO [2]. OAB could involve several different pathophysiologies and the therapeutic outcome of OAB might vary owing to the diversity of diagnosis. Therefore, the search for a biomarker to predict OAB has been a subject of increasing interest to researchers in urology.

Significant increases in bladder wall thickness (BWT) measured by transabdominal ultrasound have been found in patients with bladder outlet obstruction (BOO) [3–5]. An increased BWT and bladder wall mass were highly correlated with the degree of BOO [6]. Transvaginal ultrasound assessment of the mean BWT was also shown to be a sensitive screening tool to detect DO in women with equivocal laboratory urodynamics [7]. A BWT >2.9 mm had a positive predictive value of 100% and a sensitivity of 43% in the diagnosis of BOO in men and could replace pressure flow study [8]. Previous study showed that measurement of detrusor wall thickness (DWT) could detect BOO better than free uroflowmetry, postvoid residual urine (PVR) or prostatic volume [5]. BWT has also been used in the diagnosis of dysfunctional voiding in children with recurrent urinary tract infection [9]. A thick bladder wall was significantly associated with an abnormal bladder in nocturnal enuresis in children. BWT in children can provide useful predictive clues, which may be helpful to differentiate treatment subtypes, guide clinical management and minimize the need for invasive urodynamic studies [10]. However, the resolution of ultrasound and accurate identification of the bladder wall varied greatly in previous ultrasound studies of BWT. The differences in methodology used to measure BWT resulted in a wide variation of BWT in patients with BOO, with values ranging from 2.0 mm to 5.0 mm [3–5,7,8].

Since patients with OAB may have frequent detrusor contractions during the storage phase, it is possible that sustained isometric detrusor contractions could result in increased muscle bulk and, hence, increased BWT. However, a recent study reported that BWT did not differ among healthy controls, patients with BOO, patients with DO and patients with increased bladder sensation [9]. Thus, further confirmation of the extent of the difference in BWT between patients with OAB and control subjects is needed. This study measured DWT in men and women with OAB. If patients with OAB have a greater DWT, then measurement of DWT could be a useful biomarker for assessing the therapeutic response in patients with OAB.

2. Materials and methods

We examined DWT in patients who visited the urology clinic of the hospital. There were several patient subgroups in the study sample including those who were free of lower urinary tract symptoms (LUTS), those with symptoms of urgency frequency but not urgency incontinence (OAB dry) and those with symptoms of urgency frequency and urgency incontinence (OAB wet). Patients with neurogenic voiding dysfunction, BOO or urinary tract infection were excluded at the time of enrolment. This study was approved by the institutional review board of the hospital and informed consent was obtained from all patients before participation in the study.

Control subjects were patients who had non-urinary tract disorders and were free of LUTS. They had conditions such as inguinal hernia, phimosis, microscopic hematuria, lower leg edema and lower back pain. Patients with OAB wet and OAB dry presented with symptoms of urgency and frequency with or without urgency incontinence, respectively. The presence of OAB was further verified by a 3-day voiding diary. All patients were examined before they received medical treatment.

Patients were requested to drink 500–1000 mL of water until they felt a full bladder. DWT was measured with an 8-MHz transabdominal sonographic probe (E8C, GE model LOGIQ P5/A5; GE Healthcare, Milwaukee, WI, USA) with a full bladder. The sonographic probe was placed without pressure on the midline of the lower abdomen and scanning was performed perpendicular to the bladder wall. Increasing sonographic magnification was used to obtain a high resolution picture of the bladder wall. Three measurements were performed at the widest location of the anterior bladder wall and the DWT was obtained as the average of these three measurements. During measurement of the detrusor wall, a careful examination was performed to identify the posterior rectus fascia and distinguish it from the true bladder wall (Fig. 1A). DWT was determined by measuring the distance between the upper margins of the two hyperechoic lines on the detrusor wall (Fig. 1B).

Uroflowmetry and PVR volume were measured immediately after the transabdominal sonographic study. The maximum flow rate (Qmax) and voided volume were obtained with a uroflowmeter and the PVR was measured by transabdominal sonography of the bladder using a 4-MHz convex probe (GE, 4C; GE Healthcare) (Fig. 2A). The urinary bladder was assumed to be spherical and the bladder volume was calculated using the software in the sonographic equipment with the following equation: bladder volume $=\pi/6\times(X\ Y\ Z)$, where X, Y and Z represent the measured distances of the largest transverse measurement, longitudinal measurement and depth of the bladder. The total bladder volume was calculated as the sum of the voided volume and the PVR.

The measured DWT at various bladder volumes was then corrected to the equivalent DWT at a constant volume of 250 mL by the following equation: $DWT_2 \times R_2 = DWT_{250} \times R_{250}$ (Fig. 2B). The radius (R) of

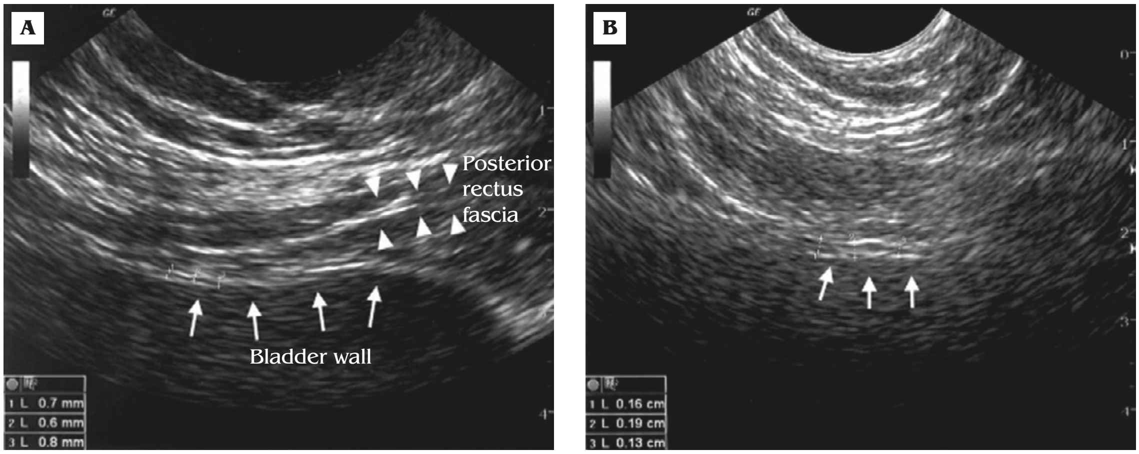

Fig. 1 — Transabdominal sonography of the bladder wall. (A) The bladder wall is traced laterally to separate the posterior rectus fascia (arrowheads) and true bladder wall (arrows). (B) Detrusor wall thickness is determined by measuring the distance between the upper margins of the two hyperechoic lines on the bladder wall.

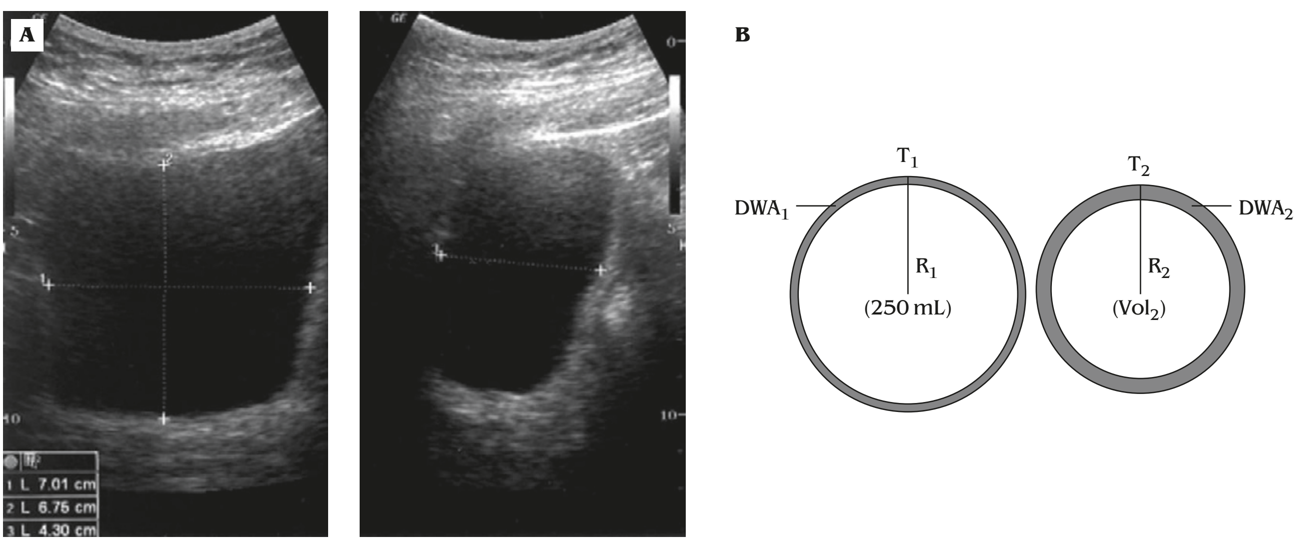

Fig. 2 — The method of correction of detrusor wall thickness to a bladder volume of 250 mL. (A) The bladder volume is calculated by the following equation: volume=$\pi/6 \times (X\ Y\ Z)$, where X, Y and Z represent the measured distances of the largest transverse measurement, longitudinal measurement and depth of the bladder. (B) The detrusor wall area (DWA) is assumed to be constant at different bladder volumes.

(1) $DWA_1 = DWA_2$

T_1 is the thickness of the detrusor wall at a volume of 250 mL.
R_1 is the radius of the bladder at a volume of 250 mL.
T_2 is the thickness of the detrusor wall at volume 2.
R_2 is the radius of the bladder at volume 2.

(2) $\pi\ (T_1+R_1)^2 - \pi R_1{}^2 = \pi\ (T_2+R_2)^2 - \pi R_2{}^2$

(3) $\pi T_1{}^2 + 2\ \pi T_1 R_1 = \pi T_2{}^2 + 2\ \pi T_2 R_2$

(4) $T_1{}^2 + 2\ T_1 R_1 = T_2{}^2 + 2\ T_2 R_2$

(5) $T_1\ (T_1 + 2\ R_1) = T_2\ (T_2 + 2\ R_2)$

Because T is smaller than R, (T+2R) can be regarded as equivalent to 2R.

(6) $T_1\ (2\ R_1) = T_2\ (2\ R_2)$

(7) $T_1/T_2 = 2\ R_2/2\ R_1 = R_2/R_1$

(8) $T1 = R_2/R_1 \times T_2$

Table 1 — Qmax, PVR and voided volume in all subgroups

	Qmax (mL/s)	PVR (mL)	Volume (mL)
Control			
Men (n=32)	15.8±10.8	35.4±33.3	369±194
Women (n=37)	24.1±13.4	63.4±82.8	361±188
	p=0.010	p=0.091	p=0.870
OAB dry			
Men (n=48)	15.4±6.4	63.0±63.9	304±152
Women (n=41)	21.0±11.4	62.9±60.5	319±206
	p=0.017	p=0.991	p=0.700
OAB wet			
Men (n=21)	11.3±7.8	65.1±62.2	254±125
Women (n=29)	22.7±10.9	67.6±65.6	226±120
	p=0.001	p=0.891	p=0.438

Qmax = maximum flow rate; PVR = postvoid residual; OAB = overactive bladder.

the bladder was obtained from the bladder volume as $4\pi/3 \times R^3$. However, because a previous study showed that there is no significant change in DWT with increasing volumes at bladder volumes over 250 mL [11], we only corrected the DWT for bladder volumes less than 250 mL. DWT at volumes greater than 250 mL was not corrected. The measured DWT, bladder volume, corrected DWT, Qmax and PVR were compared among subgroups. Results were compared between men and women and among the controls, OAB dry and OAB wet subgroups. One-way analysis of variance (ANOVA) and *post-hoc* comparison analysis were performed for subgroups in men and women. Student's t test was used for comparison of subgroups between men and women. A p value of less than 0.05 was considered statistically significant.

3. Results

A total of 208 patients were enrolled in this study, including 69 controls, 89 patients with OAB dry and 50 patients with OAB wet. There were 101 men and 107 women. The mean age of the men and women with OAB was significantly older than the controls. The mean age of the men with OAB dry was also significantly older than that of the women with OAB dry; however, no age difference was noted between the men and women with OAB wet.

Because the bladder wall is very close to the posterior rectus fascia when the urinary bladder is distended, we found that it is easy to misidentify the posterior rectus fascia as the outer layer of the bladder wall during DWT measurement. To avoid this pitfall, it is important to trace the detrusor wall laterally to separate the posterior rectus fascia and the true bladder wall (Fig. 1A).

The voided volume, Qmax and PVR in all subgroups are shown in Table 1. There were no significant differences in the voided volume and PVR between men and women or among all subgroups. The Qmax in all subgroups was significantly smaller in the men than the women. However, no significant difference was noted among subgroups for men or women.

The values of DWT, bladder volume and corrected DWT in all subjects are shown in Table 2. The corrected DWT values in all subgroups are shown in Fig. 3. There was a wide variation in DWT among the subgroups.

The values for DWT in all patients with OAB dry (1.40±0.36 mm) and OAB wet (1.55±0.44 mm) were significantly higher than in the controls (1.13±0.31 mm). However, the main contributor to this significant difference was the DWT values in the men with OAB dry (1.49±0.31 mm) and OAB wet (1.64±0.45 mm), which were higher than in the women with OAB dry (1.30±0.40 mm) and OAB wet (1.48±0.43 mm). Both men and women with OAB wet had a significantly smaller bladder volume than the controls. The measured DWT was significantly greater overall in the men and women with OAB, but the corrected DWT was significantly greater than in the controls only in the men with OAB. After correction for the bladder volume factor, the DWT values in the OAB dry and OAB wet groups were still significantly higher in men (1.41±0.30 mm and 1.50±0.48 mm, respectively; $p<0.0001$) but not in women (1.21±0.36 mm and 1.32±0.39 mm, respectively, $p>0.05$) when compared with the controls. Men with OAB dry had a significantly higher corrected DWT than women (p=0.018), but no significant difference in the corrected DWT was found between men and women with OAB wet (p=0.165).

4. Discussion

This study found a significant difference in DWT between men and women with OAB. Male patients with OAB dry and OAB wet had a significantly greater corrected DWT than men in the control group, but a

Table 2 — DWT values in controls and patients with OAB dry and OAB wet

	Men (n=101)	Women (n=107)	Total (n=208)	Statistics (men *vs.* women)
Control	n=32	n=37	n=69	
Age	55±16	49±16	52±16	p=0.090
Measured DWT	1.07±0.29	1.17±0.33	1.13±0.31	p=0.183
Bladder volume	369±194	361±188	365±190	p=0.870
Corrected DWT	1.02±0.24	1.11±0.32	1.07±0.29	p=0.206
OAB dry	n=48	n=41	n=89	
Age	71±13*	61±16†	66±15*	p=0.002
Measured DWT	1.49±0.31*	1.30±0.40	1.40±0.36*	p=0.018
Bladder volume	304±152	319±206	311±178	p=0.700
Corrected DWT	1.41±0.30*	1.21±0.36	1.31±0.34*	p=0.005
OAB wet	n=21	n=29	n=50	
Age	73±13*	70±14*	71±13*	p=0.321
Measured DWT	1.64±0.45*	1.48±0.43†	1.55±0.44*	p=0.216
Bladder volume	254±125	226±120†	238±121†	p=0.438
Corrected DWT	1.50±0.48*	1.32±0.39	1.39±0.44*	p=0.165
Total OAB	n=69	n=70		
Age	71±13*	64±16†		p=0.005
Measured DWT	1.53±0.36*	1.38±0.42†		p=0.021
Bladder volume	289±145†	281±181†		p=0.768
Corrected DWT	1.43±0.36*	1.25±0.38		p=0.005
Statistics (OAB *vs.* Control)	*p<0.0001 †p<0.05	*p<0.0001 †p<0.05	*p<0.0001 †p<0.05	

*p<0.0001 and †p<0.05, versus controls. OAB = overactive bladder; DWT = detrusor wall thickness.

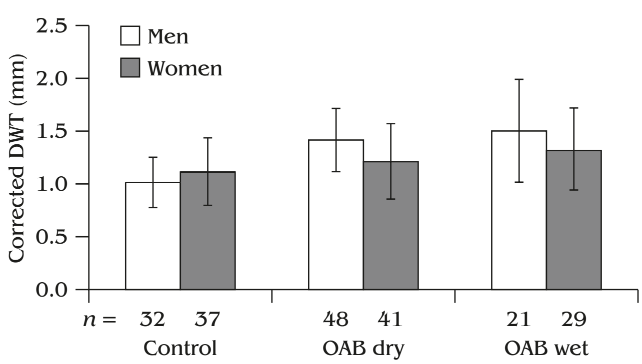

Fig. 3 — Corrected detrusor wall thickness (DWT) values in all study subjects.

similar difference in DWT was not found in women with OAB.

Although several previous studies have investigated the diagnostic value of DWT in male BOO (3–6,8), few have investigated its diagnostic value for OAB. A recent study reported finding a slightly thicker bladder wall in men with voiding dysfunction than in women, although this difference was not significant after exclusion of men with BOO (12). A mean BWT >5 mm was found to be a sensitive screening method for diagnosing detrusor instability in symptomatic women without outflow obstruction; however, the measurement was performed by transvaginal ultrasound with an empty bladder (13). None of the patients in this study had a DWT of that thickness even when measured at a small bladder capacity.

OAB is a symptomatic syndrome characterized by urgency frequency with or without urgency incontinence. The diagnosis of OAB is based on symptoms and no metabolic or anatomical disorders have been found in these patients (14). However, the underlying pathophysiology might include occult neuropathy, mild BOO, bladder dysfunction or metabolic dysfunction (15). BOO may cause DO, and the symptom of urge incontinence is strongly correlated with DO in men. Hyman et al found that a higher incidence of DO was more closely associated with urgency incontinence than with other LUTS in men. Sixty-eight percent of the men with LUTS had BOO, including 46% with concomitant DO (16). The mean age of men with OAB in this study was significantly older than that of the controls, and the DWT in men in the control group was similar to that in women in the control group, suggesting that aging and occult BOO that was not detected on enrolment might be the causes of a greater DWT in men with OAB. Our results showing that DWT was significantly greater in men than in women with OAB might reflect a different underlying pathophysiology of OAB between genders.

In this study, DWT in women with OAB was not greater than in the controls. This result is similar to the findings of Blatt et al (12), but was quite different from that of Khullar et al who found that DWT in women with OAB was significantly greater than in controls (13). The actual pathophysiology of OAB has not been fully delineated. Recent studies have postulated that urothelial dysfunction, abnormal expression of sensory receptors, increased excitability of the detrusor muscles and central nervous system sensitization may contribute to the development of OAB [17]. Although BOO can also be detected in women with OAB, the incidence of BOO in women is lower than that in men [18]. Most women with OAB do not have BOO. This explains why DWT in the women with OAB was not significantly different from that of the controls, but was significantly less than that of the men with OAB. However, there was no significant difference in DWT between men and women in the control group. This result is different from the findings of Oelke et al in healthy adults in which men had a greater DWT than women [11]. This gender difference of DWT in OAB patients may have been caused by occult BOO in the men with OAB, although these patients did not report voiding dysfunction in this study.

The differences in the values of DWT obtained in various previous studies may have been caused by the use of different ultrasound probes with different frequencies as well as to differences in the resolution of images. Our review of previous reports found that studies using a higher frequency probe (7.5 MHz) reported a DWT of around 1–2 mm [5,8,12], whereas those using a low frequency probe (2–5 MHz) reported a greater DWT of around 4–5 mm [3,4,7,13]. In the present study, we used an 8-MHz high frequency probe to measure the bladder wall. Because the resolution power was able to differentiate the detrusor wall from the posterior rectus fascia, the measured DWT tended to be much less than would have been obtained using a 2–5 MHz low frequency probe. Although low intraobserver and interobserver variability has been reported [19], careful identification of the true bladder wall and accurate placement of cursors to measure DWT require experience.

Most previous studies used a fixed bladder volume to measure DWT [3–5,8,13]. Oelke et al found a hyperbolic relationship between an increasing volume and decreasing DWT, with no significant changes in DWT with increasing bladder volumes beyond 250 mL [11]. It seems reasonable to expect that DWT decreases as the bladder volume increases; therefore, comparison of DWT between subgroups needs correction for bladder volumes less than 250 mL. In addition, the fluid volume infused into the bladder might be increased because of diuresis when the patient is lying supine. Under these considerations, the bladder volume should be measured as the voided volume plus the PVR to minimize the inaccuracy of sonographic measurement. As shown in Fig. 3, we assumed the bladder to be a spherical container, which allowed the measured DWT to be corrected to a constant volume (250 mL in this study) and the results compared among patients with different bladder volumes. Interestingly, we found that the difference in the corrected DWT value between OAB patients and controls remained the same as that of the measured DWT between these groups. This volume correction method might be a more suitable method in clinical application to measure DWT when assessing bladder dysfunction.

Although there were statistically significant differences in DWT among groups, the differences were small. We are not certain of the clinical significance of a 0.2–0.4 mm difference in thickness between the controls and patients with OAB. Moreover, whether a 0.2–0.4 mm difference in thickness can be reproduced with repeated measurements by different investigators in different centers using different machines needs further investigation.

5. Conclusion

DWT was increased in men but not in women with OAB, suggesting differences in the pathophysiology of the bladder outlet or in the effects of aging in men. The DWT of women with OAB was not significantly different from that of controls. Based on our results, we do not recommend using DWT as a biomarker for assessing OAB in women.

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