The role of ultrasonographic measurement of bladder and detrusor wall thickness in diagnosis of urinary incontinence

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Original Article

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ABSTRACT

Objective: To evaluate the diagnostic accuracy of the bladder wall thickness (BWT) and detrusor wall thickness (DWT) measurements by transvaginal ultrasound in diagnosis and classification of urinary incontinence.

Design: 51 women with pure stress urinary incontinence (SUI), 53 women with pure detrusor over activity incontinence (DOI) which both were diagnosed by urodynamic studies and 50 women without urinary incontinence (as controls) enrolled in this prospective cross-sectional study.

Settings: Using transvaginal probe, BWT was measured in three sites: at the thickest part of the dome of the bladder, the trigone, and the anterior wall of the bladder. Measurements are taken first at 250-300 ml bladder volume and repeated after voiding at <50 ml bladder volume.

Subjects: An average of the three measurements was considered as the mean BWT and DWT.

Intervention: BWT and DWT at both empty and full bladder were significantly thicker in DOI group than in controls. DOI group measurements were also thicker than SUI group except for DWT measurement in full bladder.

Main Outcome Measure: There were no statistical difference at DWT and BWT measurements between SUI and control groups.

Results: By using ROC curve analysis, the best cut off values for predicting the DOI were calculated as 4.35 mm for full BWT; 1.95 mm with for full DWT; 5.95 mm for empty BWT and 2.25 mm with for empty DWT.

Conclusion: Transvaginal ultrasonographic measurement of BWT and DWT in full and empty bladder can be valuable in diagnosis of DOI with low sensitivity and relatively high specifity.

KEY WORDS: transvaginal ultrasonography, urinary incontinence, wall thickness

INTRODUCTION

Urinary incontinence (UI) is a common condition among women defined as the complaint of any involuntary leakage of urine. It affects sexual, social and physical activities of a woman. The prevalence of UI has been determined at different values in different studies ranging from 16.1 to 68.8% [1-3]. UI mainly presents as either stress UI (SUI), detrusor over activity incontinence (DOI), or mixed UI (MUI). SUI is defined as a loss of urine that happens during situations within increase of intraabdominal pressure such as exertion, coughing or sneezing. DOI is incontinence that accompanies a strong desire for urinating due to an involuntary detrusor contractions during the bladder filling phase, appearing spontaneously or after provocation. And, MUI is defined as urine loss that happens both with exercise, coughing and sneezing and with a strong desire of urinate [4].

Differentiation of UI subtypes in primary care based on patient's complaints, history or physical examination is not always sufficient. Thus, further methods may be needed to investigate the symptoms. Urodynamic study tries to find the condition in which UI occurs and is considered as a gold standard diagnostic tool for evaluating lower urinary tract symptoms. However, it is an expensive, time consuming, invasive and not easily accessible method [5]. Therefore, there is a growing number of researches to find a noninvasive, cheap and widely available method for assessing lower urinary tract symptoms. Ultrasound is a that kind of diagnostic tool with widespread use in obstetrics and gynecology practice. Although there is no standardization about the method, some previous studies have suggested that measurement of bladder and detrusor wall thickness via ultrasound is a reliable method of diagnosis of UI subtypes [6, 7].

In this study, we aimed to determine the diagnostic role of transvaginal ultrasound measurement of BWT and DWT in determining the UI subtype in the full and empty bladder.

SUBJECTS AND METHODS

This prospective cross-sectional case control study was carried out at Zekai Tahir Burak Women's Health Education and Research Hospital between March 2015 and October 2016. Patients admitted to the urogynaecology outpatient clinic with complaint of urinary incontinence were included. The study was approved by the ethical research committee of the hospital. Written and verbal information was given to all the patients and their signed approvals were taken. Patients with any systemic disease, drug use history affecting the urinary system, urinary system obstruction, current urinary system infection or recurrent urinary tract infection history, > grade 2 pelvic organ prolapse according to the Baden-Walker classification system, MUI and pelvic surgery history were excluded from the study.

We included 104 incontinent patients as cases and 50 continent patient as controls. Continent patients were women who were referred to gynecology outpatient clinic due to the gynecological diseases other than UI like fibroids or adnexial cysts. All patients subjected to detailed history, general physical and urogynaecological examination. Of 104 incontinent patient, 51 women were diagnosed with SUI and 53 women were with DOI based on urodynamic test results. Urinalysis was performed for all patients to exclude any pyuria or bacteriuria before urodynamic test. Urodynamic examinations were performed using MMS Solar Blue multijointed urodynamic system when the patients were in sitting position, according to International Continence Society recommendations [8]. The urodynamic findings of the patients were evaluated by physicians working in the urogynecology clinic but not in the study team.

For all patients, ultrasonographic measurements were performed using Aloka ProSound SSD 5500 SV Pure HD (Aloka Co Ltd, Tokyo, Japan) with the vaginal 7 Mhz probe in supine position. Ultrasound examinations were made by one author who was blind to urodynamic study results. For cases, ultrasound was not performed in combination with urodynamic test on the same day. Before the measurements of BWT and DWT, the amount of urine in the bladder was calculated using the formula described by Haylen [9]. Initially, BWT and DWT were measured on the sagittal plan while the bladder was 250-300 cc full. Then, patients were asked to void. Following the urination, BWT and DWT were measured as the residual urine volume was <50 cc. During measurements, the vaginal probe was careful not to press on the bladder. BWT and DWT were measured as described by Oelke and Robinson *et al* [5, 10]. The bladder was first displayed on the sagittal plan. In this position, the hypoechoic urethra, which caused the shadowing of the bladder dome, was displayed. Subsequently, the probe was shifted laterally 1 cm. When measurements were taken, the bladder was maximally enlarged to cover the entire screen. The bladder wall was ultrasonographically displayed as a 3-layered hypoechoic area between the two hyperechoic areas. In this image, the hypoechoic area forms detrusor wall when hyperechogenic areas form adventitia and mucosa.

BWT with including 3 layers was measured from the outside to the outside. DWT was also measured in such a way as to measure only the hypoechoic area and to be perpendicular to the bladder lumen from outside to outside. Three different measurements were taken from the bladder dome, trigone, and bladder anterior wall, and their average was calculated and accepted as the final value. Intra-observer reliability was assessed using the measurements of the first investigator (T.S.L. who was blind to urodynamic study results and performed all measurements) with an interval of 7–14 days and was blinded to the previous analysis. For interobserver reliability test, another author, was blinded to first author's results and urodynamic findings, repeated the ultrasonographic measurements for the first 20 cases. Test–retest series for all parameters in the first 20 patients were measured and showed good interobserver agreement. Intra-observer intraclass correlation coefficient ranged from 0.648 to 0.886.

When the size of the sample was calculated for our study, previous studies [10- 12] with BWT measurement difference of 1 mm were taken as a reference between female patients with and without UI diagnosis. As a result, it was estimated that for detection of a 1 mm difference between groups, each group should consist of 48 females with a power of 80% and a 5.0% alpha error.

SPSS (Statistical Package for Social Sciences) for Windows 17.0 program was used for statistical analysis. Whether or not the data had normal distribution was checked by the Kolmogorov-Smirnov test. Those with normal distribution of quantitative data are shown as mean ± standard deviation and those without normal distribution as median (minimum-maximum value). The One-Way ANOVA test was used to compare the differences between groups with normal distribution and when the difference was significant a post-hoc Tukey test was used to identify the group that caused the difference. Differences, between groups without normal distribution were assessed by Kruskal Wallis test. Qualitative data were presented as number (%) and Chi-square test was used to investigate the differences among the groups consisting of these data. The receiver-operating characteristic (ROC) curve was created to measure the predictive sensitivity and specificity of DOI measurements of different ultrasonographic full BWT measurements. Multiple logistic regression analysis was used to identify those who had the most significant effect from the risk factors considered to be impacted on the full, empty BWT and DWT increases. For each independent variable odds ratio, 95% confidence interval and significance levels for were calculated. For $p < 0.05$, the results were considered statistically significant.

RESULTS

A total of 154 women were enrolled, 51 of which were SUI, 53 were DOI, and 50 were control group. There were no statistically significant differences between the groups in terms of demographic characteristics as shown in Table 1.

According to the ultrasonographic measurements, statistically significant difference was found in all of full BWT, full DWT, empty BWT and empty DWT values between SUI, DOI and control groups (Table 2). The mean values of full BWT were measured as 3.7 ± 0.8 mm in the SUI group, 4.8 ± 1.7 mm in the DOI group and 4.0 ± 0.8 mm in the control group. The mean values of full DWT were measured as 1.5 ± 0.5 mm in the SUI group, 1.6 ± 0.5 mm in the DOI group and 1.3 ± 0.4 mm in the control group. The mean values of empty BWT were measured as 4.5 ± 1.2 mm in the SUI group, 6.0 ± 1.9 mm in the DOI group and 4.7 ± 1.0

mm in the control group. The mean values of empty DWT were measured as 1.7 ± 0.7 mm in the SUI group, 2.4 ± 1.0 mm in the DOI group and 1.7 ± 0.6 mm in the control group (p <0.001). All wall thickness measurements in DOI group were significantly greater than in control group. Similarly, full BWT, empty BWT and empty DWT measurements were greater in DOI group than in SUI group, but there was no significant difference between SUI and DOI groups for full DWT. On the other hand, SUI and control groups were statistically similar in terms of all wall thickness measurements (Table 2). When we compared four different ultrasonographic measurement ratios, there was only a statistically significant difference between the groups regarding to full BWT/full DWT ratio (p=0.039) (Table 2). Namely, full BWT/full DWT ratio was statistically greater in DOI group (3.2±1.1 mm) than in SUI group (2.8±1.0 mm) (p=0.046).

Figure 1 shows the generated ROC curve for ultrasonographic measurements of different BWT and DWT in predicting SUI. However, no statistically significant relationship was found between any ultrasonographic measurement and presence of SUI (all p values >0.05) (Table 3). On the other hand as seen in Figure 2, the curves plotted for full BWT, Full DWT, Empty BWT and empty DWT are above the 45° line, indicating a significant relationship between each of these values and the presence of DOI [For full BWT, Area Under Curve (AUC)=0.68, Standard Error (SE)=0.05, 95% Confidence interval (CI)= 0.58-0.78, p=0.002; for full DWT AUC=0.63, SE=0.06, 95%CI=0.52-0.74, p=0.023; for empty BWT AUC=0.72, SE=0.05, 95%CI=0.62-0.82, p<0.001; for empty DWT AUC=0.74, SE=0.05, 95%CI=0.64-0.83, p<0.001]. But for Full BWT / full DWT ratio, there was no relationship between the presence of DOI (p = 0.345) (Table 4).

The best cut off values for predicting the DOI are; 4.35 mm with 59% sensitivity and 76% specificity for full BWT; 1.95 mm with 36% sensitivity and 90% specificity for full DWT; 5.95 mm with %51 sensitivity and %90 specificity for empty BWT and 2.25 mm with %57 sensitivity and %82 specificity for empty DWT (Table 4). The most statistically significant among these parameters are empty DWT (AUC = 0.74), empty BWT (AUC = 0.72), full BWT (AUC = 0.68) and full DWT (AUC = 0.63).

Multivariate regression analysis was used to determine which variables were independent predictors for BWT and DWT increase in full and empty bladder (Table 5). After controlling possible confounders, the presence of urge incontinence was determined as the only significant independent factor for full BWT increase (p <0.001). For empty BWT increase, it was found that woman's age ≥60 years (p=0.008) and presence of DOI (p <0.001) were significant independent variables. When the same analysis was performed for DWT increase in full and empty bladder, BMI≥ 30 kg/m^2 (p = 0.034) and presence of DOI (p = 0.013) was found to be independent effective factors for full BWT increase. Additionally, presence of DOI (p <0.001) and menopausal status (p = 0.037) were independently effective in terms of empty DWT increase.

DISCUSSION

In this study, we have found that transvaginal ultrasonographic BWT and DWT in full and empty bladder is associated with presence of DOI and can be useful in diagnosis of urinary incontinence as a noninvasive, cheap and accessible method. It has been shown that BWT or DWT increases in DO [13]. It is believed that patients with DO have frequent isometric detrusor contractions during storage phase. Secondary to these contractions, muscle bulk increases and bladder wall hypertrophy occurs. Therefore, BWT or DWT increases [14]. In our study, we have found that ultrasonographic measurements of both BWT and DWT in full and empty bladder were greater in patient with DOI than in continent women. Also, presence of DOI was detected as independent factor for BWT and DWT increase in full and empty bladder. Our results indicate a possible bladder wall hypertrophy in diagnosis of DOI.

It is known that BWT and DWT can be measured ultrasonographically by three different approaches which are transvaginal, transperineal and suprapubic, and all of these methods are effective in determining detrusor hypertrophy; However, these methods have been reported to vary in terms of image quality, necessity of bladder filling during measurement, and invasiveness rates [15]. We preferred transvaginal ultrasonography in our study because of its reliability in obese patients with minimal bone and soft tissue artefact, and higher frequency of the probe measurements [16].

In healthy women BWT measurement ranges from 3 to 5 mm and until 50 ml of bladder fullness BWT does not change significantly; between 50-250 ml BWT thins down rapidly and above 250 ml it tends to remain constant [15-17]. Therefore, in our study, empty bladder measurements for BWT and DWT were performed with a bladder volume <50 cc and full bladder measurements with a volume of 250-300 cc.

Previous studies using ≥5 MHz transvaginal probe have noted significantly higher BWT measurements in patients with DO than in SUI or continent women but cut–off values for diagnosis of DO varied between the studies [18, 5, 12]. Khullar *et al* stated that the mean BWT >5 mm had a sensitivity of 84% and specificity of 89% for diagnosis of detrusor overactivity [19]. However, Robinson *et al* proposed a BWT cut off of 6 mm as a highly suggestive value for DO [10]. Serati *et al* evaluated the BWT measurements in different incontinence types and found that a cut-off value of 6.5 mm had a 100% positive predictive value for all DO (including DO associated with SUI), and 71.4% for pure DO, but this method could not replace urodynamic test [20]. In 2010, a systematic review performed by Latthe *et al*, after assessment of the methodological quality of 190 studies, included only 5 for further analysis concuded that using a 5-mm cut-off for BWT for identifying DO, the sensitivity varied between 40% and 84%, and specificity 78-89% [21]. All of these studies were performed by transvaginal ultrasound at <50 ml. About DWT, there is few data published for women. Kuo measured DWT via transvaginal ultrasonography and did not found an increased in women with DO compared with other diagnoses [14]. However, in Kuo's study measurements were taken from the bladder neck, anterior wall, posterior wall and bladder base, rather than the more commonly used trigone, anterior wall and dome. In another study by Lekskulchai *et al*[12] DWT was measured at three different sites (trigone, dome and anterior wall) and the mean calculated after voiding with a ≤50 ml bladder volume by translabial approach. They reported higher mean DWT values in DO group than in non DO group, and also DWT measurement had poor sensitivity but high specificity for diagnosing DO. Minardi *et al* reported similar results in a prospective, controlled, study confirming that translabial measurement of DWT was higher in women with DOI than in women with SUI or healthy controls [6]. In this study, we measured both BWT and DWT in full and empty bladder via transvaginal ultrasonography. We found that these parameters increased in DOI group compared to SUI and continent group. And we determined that a full BWT >4.35 mm predicted DOI with a sensitivity of 59% and a specificity of 76%; a full DWT >1.95 mm with a sensitivity of 36% and a specificity of 90%; an empty BWT >5.95mm with a sensitivity of 51% and a specificity of 90%; an empty BWT >2.25 mm with a sensitivity of 57% and specificity of 82%. This low sensitivity and relatively high specificity values make think that BWT and DWT measurements by transvaginal ultrasonography may be useful parameters for clinicians to confirm the presence of DOI, especially to identify women who are unlikely to have DOI.

Our study has some strong sides. There is a lack of data in literature about the role of ultrasonographic measurement of BWT in prediction of SUI. In our study, we could compare both BWT and DWT in full and empty bladder between SUI and continent group. We have found that BWT and DWT have no predictive role in diagnose of SUI. In addition when the literature is reviewed, it is seen that there is no proportional calculations including BWT and DWT in any study other than our work, and also it seen that the importance of that in diagnose not taken into consideration. We also compared four ratios between the groups and did not report any predictive role for any ratio. But we believe that these topics need some more studies to reach exact recommendations. In our study, the presence of a sufficient number of patients with homogenous demographic characteristics seems to be an advantage to minimize biased errors for the interpretation of the results of ultrasonographic measurements. We also think that there is not sufficient data in the literature for measurements in the presence of full bladder, and the examination of these data in our study creates awareness for our work. On the contrary, we think that our results are disadvantage in accepting for wider populations because our study is done only in Turkish society and the exclusion of some factors that may be effective in urinating physiology.

CONCLUSION

Transvaginal ultrasonographic measurement of BWT and DWT in full and empty bladder can be useful in diagnosing of urinary incontinence subtype. This leads to future studies to strengthen the use of ultrasonography, which is less invasive, easier to access and cheaper than using urodynamics to diagnose UI.

ACKNOWLEDGMENT

Conflict of interest: The authors report no conflict of interest.

Funding: This study was not financially supported by any founding. It was originally conducted as a graduation thesis in Obstetrics and Gynecology.

OS Kıncı : Project development, Data Collection, Manuscript writing

MF Kıncı : Data collection, Manuscript writing

MK Kokanalı : Project development, Manuscript writing

Y Taşçı : Project development

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Table 1: Demographic characteristics of the groups

Demographic characteristics	SUI (n=51)	DOI (n=53)	Control (n=50)	P
Woman's age (years)	47.8±7.2	47.9±9.7	46.1±8.8	0.527
Gravida	3 (1-10)	4 (1-13)	3 (0-8)	0.130
Parity	2 (1-5)	2 (0-7)	2 (0-7)	0.240
BMI (kg/m^2)	30.0±6.2	29.1±6.2	28.8±5.1	0.591
No. of vaginal delivery	2 (0-5)	2 (0-7)	1 (0-7)	0.201
≥4000g birth history	8 (15.7)	8 (15.1)	15 (30.0)	0.106
Cesarean section history	7 (13.7)	7 (13.2)	12 (24.0)	0.262
Current smoking	11 (21.6)	4 (7.5)	6 (12.0)	0.105
Menopausal status	15 (29.4)	22 (41.5)	12 (24.0)	0.147

Data were presented as mean±standard deviation, median (minimum-maximum value), number (%).
SUI: stress urinary incontinence; DOI: detrusor over activity incontinence BMI: Body mass index
p<0.05 was considered statistically significant.

Table 2: Ultrasonographic measurements and ratios of full BWT, full DWT, empty BWT and empty DWT by groups

Ultrasonographic measurements	SUI -I-	DOI -II-	Control -III-	P_1	P_2		
					I-II	I-III	II-III
Full BWT	3.7±0.8	4.8±1.7	4.0±0.8	**<0.001**	**<0.001**	0.408	**0.003**
Full DWT	1.5±0.5	1.6±0.5	1.3±0.4	**0.025**	0.485	0.258	**0.019**
Empty BWT	4.5±1.2	6.0±1.9	4.7±1.0	**<0.001**	**<0.001**	0.713	**<0.001**
Empty DWT	1.7±0.7	2.4±1.0	1.7±0.6	**<0.001**	**<0.001**	0.858	**<0.001**
Full BWT/Full DWT	2.8±1.0	3.2±1.1	3.2±0.9	**0.039**	**0.046**	0.985	0.088
Empty BWT/Empty DWT	2.8±0.9	2.8±0.9	2.9±0.7	0.377	---	---	---
Full BWT/Empty BWT	0.8±0.2	0.8±0.2	0.8±0.1	0.579	---	---	---
Full DWT/Empty DWT	0.9±0.4	0.7±0.3	0.8±0.2	0.057	---	---	---

Data were presented as mean±standard deviation.
SUI: Stress urinary incontinence; DOI: Detrusor over activity incontinence; BWT: Bladder wall thickness; DWT: Detrussor wall thickness; P_1: probability value for One-Way ANOVA Test; P_2: probability values for post hoc Tukey Test
p<0.05 was considered statistically significant.

Table 3: Areas Under ROC Curve for ultrasonographic Bladder and Detrussor Wall Thickness measurements in predicting stress urinary incontinence

Ultrasonographic measurements in predicting SUI	AUC	SE	P	95% CI
Full BWT	0.41	0.06	0.102	0.29-0.52
Full DWT	0.59	0.06	0.121	0.48-0.70
Empty BWT	0.44	0.06	0.313	0.33-0.55
Empty DWT	0.52	0.06	0.674	0.41-0.64
Full BWT/Full DDT	0.33	0.05	0.303	0.22-0.44

AUC: Area under curve; SE: Standard error; CI: Confidence interval; BWT: Bladder wall thickness; DWT: Detrussor wall thickness; $p<0.05$ was considered statistically significant.

Table 4: Areas Under ROC Curve for ultrasonographic Bladder and Detrussor Wall thickness measurements in predicting detrusor over activity incontinence and cut-off values

Areas Under ROC Curve for ultrasonographic BWT and DWT	AUC	SE	P	95% CI	Cut off (mm)	Sensitivity (%)	Specificity (%)
Full BWT	0.68	0.05	**0.002**	0.58-0.78	4.25 4.35 4.45	59 59 50	74 76 80
Full DWT	0.63	0.06	**0.023**	0.52-0.74	1.85 1.95 2.05	36 36 20	86 90 94
Empty BWT	0.72	0.05	**<0.001**	0.62-0.82	5.85 5.95 6.05	53 51 49	88 90 90
Empty DWT	0.74	0.05	**<0.001**	0.64-0.83	2.15 2.25 2.35	59 57 53	80 82 82
Full BWT/Full DDT	0.45	0.06	0.345	0.33-0.56	---	---	---

AUC: Area under curve; SE: Standard error; CI: Confidence interval; BWT: Bladder wall thickness; DWT: Detrussor wall thickness; $p<0.05$ was considered statistically significant.

Table 5: Multivariate regression analysis of factors for BWT and DWT increase in full and empty bladder

Multivariate regression analysis of factors for BWT and DWT increase in full and empty bladder	Full BWT Increase				Empty BWT Increase			
	Wald	OR	%95 CI	P	Wald	OR	%95 CI	P
Age (<60;≥60 years)	0.2	0.8	0.3-2.2	0.664	7.1	9.1	1.8-45.8	**0.008**
BMI (<30; ≥30 kg/m^2)	0.1	0.9	0.4-1.9	0.756	1.0	0.6	0.2- 1.6	0.324
Vaginal delivery (Primi/multiparous)	0.5	1.5	0.5-4.8	0.459	0.1	1.0	0.2-4.0	0.948
Cesarean section	0.9	1.9	0.5-7.1	0.355	2.3	4.0	0.7-24.9	0.132
Current smoking	0.1	1.1	0.4-3.1	0.920	0.4	0.7	0.2-2.4	0.538
Menopausal status	0.1	1.2	0.4-3.3	0.755	0.2	0.7	0.2-2.8	0.633
Incontinence subtype (SUI/DOI)	17.0	4.7	2.3-9.9	**<0.001**	27.5	14.3	5.3-38.4	**<0.001**
	Full DWT Increase				**Empty DWT Increase**			
	Wald	**OR**	**Wald**	**OR**	**Wald**	**OR**	**Wald**	**OR**
Age (<60;≥60 years)	1.0	0.5	0.2-1.8	0.318	1.7	0.5	0.1-1.5	0.187
BMI (<30; ≥30 kg/m^2)	4.5	2.5	1.1-5.9	**0.034**	0.3	1.3	0.6-2.8	0.571
Vaginal delivery (Primi/multiparous)	0.3	0.7	0.2-2.6	0.588	0.4	1.5	0.4-5.2	0.504
Cesarean section	0.3	1.6	0.3-7.2	0.568	2.3	3.1	0.7-13.5	0.130
Current smoking	0.1	1.2	0.4-4.0	0.774	0.1	0.9	0.3-2.7	0.809
Menopausal status	07	1.7	0.5-5.6	0.391	4.3	3.7	1.0-12.5	**0.037**
Incontinence subtype (SUI/DOI)	6.2	2.8	1.2-6.2	**0.013**	21.6	6.7	3.0-15.1	**<0.001**

BWT: Bladder wall thickness; DWT: Detrussor wall thickness BMI: Body mass index; SUI: Stress urinary incontinence; DOI:Detrusor over activity incontinence; OR: Odds ratio; CI: Confidence interval

p<0.05 was considered statistically significant.

Fig 1: Receiver-operating characteristic curve of transvaginal ultrasonographic bladder and detrussor wall thickness measurements and stress urinary incontinence

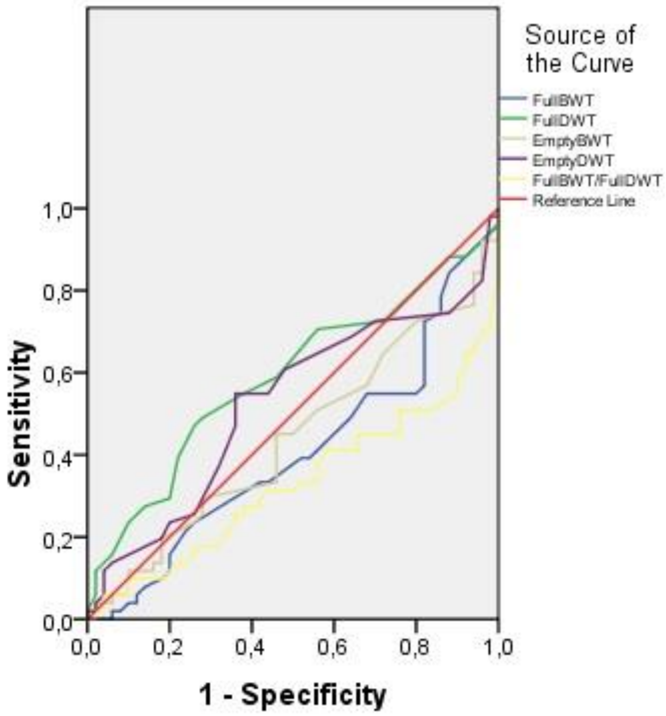

Fig 2: Receiver-operating characteristic curve of transvaginal ultrasonographic bladder and detrussor wall thickness measurements and detrusor over activity incontinence