Original Article - Lower Urinary Tract Dysfunction

Investig Clin Urol 2020;61:491-497.
https://doi.org/10.4111/icu.20190376
pISSN 2466-0493 • eISSN 2466-054X

INVESTIGATIVE AND CLINICAL UROLOGY
ICUROLOGY

Bladder wall thickness and detrusor wall thickness can help to predict the bladder outlet obstruction in men over the age of 70 years with symptomatic benign prostatic hyperplasia

Juhyun Park[1], Jungyo Suh[2], Sangjun Yoo[2], Min Chul Cho[2], Hwancheol Son[2]

[1]Department of Urology, Asan Medical Center, University of Ulsan College of Medicine, Seoul, [2]Department of Urology, SMG-SNU Boramae Medical Center, Seoul National University College of Medicine, Seoul, Korea

Purpose: We investigated the possible association between preoperative bladder wall thickness (BWT) or detrusor wall thickness (DWT) and bladder outlet obstruction (BOO) based on urodynamic studies in men with symptomatic benign prostatic hyperplasia (BPH).

Materials and Methods: Data were prospectively collected from a BPH surgery database. A total of 196 men who underwent prostate vaporization for symptomatic BPH were included in this study. BWT and DWT were measured in the suprapubic area after uroflowmetry.

Results: No significant difference was noted in BWT and DWT in any patient according to the presence of BOO; however, subgroup analysis showed that BWT and DWT were significantly thicker in the obstruction group in men aged 70 years or older than in those under age 70 (BWT: 3.6+0.9 mm vs. 3.1+0.9 mm, p=0.022, DWT: 2.8±0.8 mm vs. 2.3±0.8 mm, p=0.007). In this older age group, the classification based on a BWT ≥4.0 mm showed 31% sensitivity, 87% specificity, and 65% diagnostic accuracy for the diagnosis of BOO, whereas DWT ≥3.0 mm showed 49% sensitivity, 82% specificity, and 69% diagnostic accuracy.

Conclusions: BWT and DWT were associated with BOO in men aged 70 years or older. Therefore, BWT and DWT will be a useful non-invasive parameter for deciding the management strategy for elderly men with symptomatic BPH. An appropriate measurement method should be established as soon as possible for further application of the relationship among BWT, DWT and BOO.

Keywords: Prostatic hyperplasia; Urinary bladder; Urinary bladder neck obstruction

INTRODUCTION

The evaluation of lower urinary tract symptom/benign prostatic hyperplasia (BPH) has relied on the urodynamic study as the gold standard diagnostic test of bladder outlet obstruction (BOO) [1]. However, urodynamic studies are invasive and expensive when compared to other diagnostic tools and require the expenditure of much effort by the

Received: 16 November, 2019 • **Revised:** 4 February, 2020 • **Accepted:** 5 April, 2020 • **Published online:** 16 July, 2020
Corresponding Author: Hwancheol Son https://orcid.org/0000-0001-5033-0153
Department of Urology, SMG-SNU Boramae Medical Center, 20 Boramae-ro 5-gil, Dongjak-gu, Seoul 07061, Korea
TEL: +82-2-870-2391, FAX: +82-2-870-3863, E-mail: volley@snu.ac.kr

examiner, in terms of quality control and management, to obtain accurate results [2]. Moreover, the possibility of complications, such as urinary tract infection, hematuria, and urinary retention, following a urodynamic study frequently necessitates the prescription of additional medications, including antibiotics, before and after the examination [3].

Researchers have attempted to overcome these limitations of urodynamic studies by consistently reviewing potential alternative tests. The most recent method of note involves the measurement of bladder wall thickness (BWT) and detrusor wall thickness (DWT) using transrectal or transabdominal ultrasonography. Several studies have reported a positive relationship among BWT, DWT and BOO, based on urodynamic studies in men with symptomatic BPH [4-7].

Our research team recently performed and published a preliminary study indicating that the resolution of BOO after BPH surgery is accompanied by a decrease in DWT. However, we were unable to confirm any positive association between DWT and BOO because of the small number of subjects in that study [5]. During that preliminary study, we maintained the same measurement conditions before and after surgery by assessing BWT and DWT by checking the post-void residual urine volume after uroflowmetry. We have since included BWT and DWT measurement after uroflowmetry as a routine diagnostic procedure for evaluating BPH surgery candidates, and we have continuously added to the database.

The aim of the present study was to investigate the relationship among preoperative BWT, DWT and BOO based on urodynamic studies in men with symptomatic BPH to confirm whether assessment of BWT/DWT could replace urodynamic studies.

MATERIALS AND METHODS

We reviewed a BPH surgery database prospectively collected between October 2012 and November 2016. A total of 196 men who underwent prostate vaporization for symptomatic BPH were included in this study. Patients with previous pelvic radiotherapy/surgery, previous diagnosis of prostate cancer, or neurological diseases were excluded from the analysis. All patients underwent a preoperative standard diagnostic assessment, including medical history and physical examination, and they filled out the international prostate symptom score (IPSS)/quality of life (QoL) questionnaire. Additional interventions consisted of blood tests, including tests for prostate specific antigen (PSA), and specialized studies, such as uroflowmetry, post-voided residual urine volume determinations, transabdominal/transrectal ultrasonographic measurements of prostate size, BWT, DWT, and multichannel urodynamic studies.

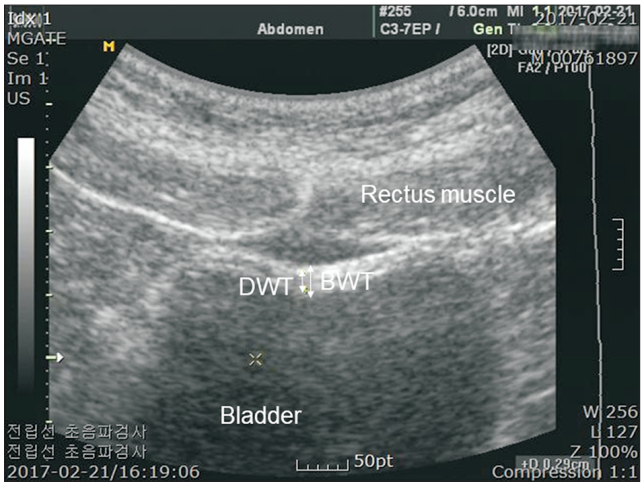

Fig. 1. BWT and DWT measurements in the same subject after uroflowmetry. BWT, bladder wall thickness; DWT, detrusor wall thickness.

BWT and DWT values were simultaneously assessed by suprapubic ultrasonography (7.5 MHz, SA-8000; Medison, Seoul, Korea) (Fig. 1). All sonographic examinations were performed by a single experienced radiologist during the postmicturition state after uroflowmetry. BOO was defined as a BOO index >40 (Pdet @ Q_{max}–2 Q_{max}), determined from the urodynamic study. We divided all patients into two groups based on age (<70 years old or ≥70 years old) and conducted a subgroup analysis according to the age group.

The study protocol was approved by the Institutional Review Board at SMG-SNU Boramae Medical Center (approval number: 16-2015-77) and the study conformed to the tenets of the Declaration of Helsinki. The planned study was explained to the patients in detail, and written informed consent was obtained from each patient.

1. Statistical analysis

Variables are presented as mean±standard deviation. Statistically significant differences of BWT and DWT according to the presence of BOO were analyzed using independent t-tests. The association among BWT, DWT and BOO was analyzed by using χ^2 test. A p-value of <0.05 was considered statistically significant, and commercially available statistical software (IBM SPSS Statistics ver. 22.0; IBM Corp., Armonk, NY, USA) was used to analyze the data.

RESULTS

The mean age of the patients was 69.5±6.9 years, and

https://doi.org/10.4111/icu.20190376

Table 1. Patient characteristics

Characteristic	Value
Patients demographics	
Patient number	196
Age (y)	69.5±6.9
Body mass index (kg/m^2)	24.2±2.8
Comorbidities	
Diabetes mellitus	37 (18.9)
Hypertension	91 (46.4)
Ultrasonography	
Prostate volume (mL)	55.8±27.8
Transitional zone volume (mL)	33.6±22.4
Bladder wall thickness (mm)	3.4±1.1
Detrusor wall thickness (mm)	2.6±0.9
Prostate specific antigen (ng/mL)	5.4±4.7
Symptom scores	
Total IPSS score	20.5±8.8
Voiding symptom subscore	12.4±5.8
Storage symptom subscore	8.2±3.9
Quality of life score	4.2±1.3
Uroflowmetry	
Q_{max} (mL/sec)	8.5±4.4
Post void residual urine (mL)	70.5±96.6
Urodynamic study	
MUCP (cmH_2O)	76.5±30.2
First desire to void (mL)	200.7±96.5
Normal desire to void (mL)	252.7±102.5
Strong desire to void (mL)	333.8±106.5
Maximal cystometric capacity (mL)	346.7±121.9
Pressure at Q_{max} (cmH_2O)	54.4±25.4
Compliance	
Good	175 (89.3)
Poor	21 (10.7)
Involuntary detrusor contraction	112 (57.1)
Bladder outlet obstruction index	40.8±32.6
Obstructed	84 (42.9)
Equivocal	64 (32.7)
Unobstructed	48 (24.5)

Values are presented as number only, mean±standard deviation, or number (%).
IPSS, international prostate symptom score; Q_{max}, maximal flow rate; MUCP, maximum urethral closure pressure.

the mean body mass index was 24.2±2.8 kg/m^2. Thirty-seven (18.9%) patients had diabetes mellitus, and 91 (46.4%) had hypertension. The mean total prostate volume and transitional zone volume was 55.8±27.8 mL and 33.6±22.4 mL, respectively. Suprapubic ultrasonography yielded a mean value of 2.6±0.9 mm for DWT and 3.4±1.1 mm for BWT. The preoperative mean PSA was 5.4±4.7 ng/mL. The preoperative total IPSS was 20.5±8.8, and the voiding symptom subscores and storage symptom subscores were 12.4±5.8 and 8.2±3.9 respectively.

Table 2. BWT, DWT and PVR according to the BOO index and age groups

BOO index	BWT (mm)	DWT (mm)	PVR (mL)
All patients			
Obstructed (n=84)	3.6±1.1	2.7±0.9	55.3±87.6
Unobstructed (n=112)	3.3±1.1	2.5±0.9	54.9±92.5
p-value	0.051	0.081	0.973
Patients <70 years old			
Obstructed (n=45)	3.6±1.2	2.6±1.0	44.6±79.1
Unobstructed (n=52)	3.5±1.2	2.6±1.0	50.7±95.2
p-value	0.537	0.979	0.734
Patients ≥70 years old			
Obstructed (n=39)	3.6±0.9	2.8±0.8	67.7±95.9
Unobstructed (n=60)	3.1±0.9	2.3±0.8	58.5±90.7
p-value	0.022	0.007	0.630

Values are presented as mean±standard deviation.
BWT, bladder wall thickness; DWT, detrusor wall thickness; PVR, post void residual urine; BOO, bladder outlet obstruction.

The QoL score was 4.2±1.3. The preoperative mean Q_{max} was 8.5±4.4 mL/s, and the preoperative mean post void residual urine was 70.5±96.6 mL. The preoperative urodynamic study revealed a mean maximal urethral closure pressure of 76.5±30.2 cmH_2O and a maximum cystometric capacity of 346.7±121.9 mL. Poor bladder compliance and involuntary detrusor contraction were present in 21 (10.7%) and 112 (57.1%) patients, respectively. BOO index was 40.8±32.6, and 84 (42.9%) patients were classified as obstructed (Table 1).

BWT and DWT values were relatively thicker in the obstruction group; however, statistical significance was not reached in all patients. Subgroup analysis showed that BWT and DWT were significantly thicker in the obstruction group in men aged 70 years or older (BWT: 3.6+0.9 mm vs. 3.1+0.9 mm, p=0.022, DWT: 2.8±0.8 mm vs. 2.3±0.8 mm, p=0.007) (Table 2).

In univariate analysis, PSA, prostate volume, and voiding symptom subscore were associated with BOO. In men aged 70 years or older, body mass index, prostate volume, voiding and storage symptom subscore, BWT and DWT were related to BOO. Multivariate analysis revealed prostate volume (odds ratio [OR], 1.031; p=0.039) and Q_{max} (OR, 0.791; p=0.037) are important parameters for predicting BOO, whereas DWT showed the tendency associating with BOO in the older age group (OR, 2.429; p=0.069) (Table 3).

In all patients, the classification by BWT ≥4 mm showed 36% sensitivity, 78% specificity, 55% positive predictive value, 62% negative predictive value, and 60% diagnostic accuracy for the diagnosis of BOO. Subgroup analysis for the men aged 70 years or older showed that BWT ≥4 mm gave 31% sensitivity, 87% specificity, 60% positive predictive values,

Table 3. Univariate and multivariate analysis for predicting BOO

Variable	Univariate	p-value	Multivariate	p-value
All patients				
Age	0.987 (0.948–1.029)	0.537	0.958 (0.897–1.023)	0.200
BMI	1.077 (0.973–1.193)	0.153	1.074 (0.909–1.269)	0.399
DM(+)	0.671 (0.319–1.413)	0.294	0.520 (0.163–1.664)	0.271
HTN(+)	1.182 (0.670–2.085)	0.563	0.863 (0.350–2.129)	0.749
PSA	1.099 (1.025–1.178)	0.008	1.092 (0.977–1.219)	0.120
Prostate volume	1.029 (1.016–1.042)	<0.001	1.039 (1.016–1.063)	0.001
BWT	1.301 (0.997–1.679)	0.053		
DWT	1.318 (0.965–1.799)	0.083	1.337 (0.821–2.175)	0.243
Voiding symptom subscore	1.086 (1.030–1.146)	0.002	1.115 (1.004–1.238)	0.042
Storage symptom subscore	1.075 (0.996–1.160)	0.062	1.007 (0.860–1.180)	0.931
Quality of life score	1.144 (0.919–1.425)	0.228	0.909 (0.589–1.401)	0.664
Q_{max}	0.935 (0.864–1.012)	0.098	0.878 (0.786–0.980)	0.021
Post void residual urine	1.000 (0.997–1.003)	0.973	1.001 (0.997–1.006)	0.540
Patients <70 years old				
BMI	0.971 (0.830–1.136)	0.711	1.014 (0.759–1.357)	0.923
DM(+)	0.646 (0.215–1.945)	0.437	0.132 (0.013–1.313)	0.084
HTN(+)	1.169 (0.518–2.638)	0.706	1.116 (0.257–4.854)	0.883
PSA	1.277 (1.094–1.490)	0.002	1.302 (0.988–1.714)	0.061
Prostate volume	1.038 (1.018–1.059)	<0.001	1.063 (1.019–1.110)	0.005
BWT	1.110 (0.800–1.542)	0.532	-	
DWT	1.005 (0.675–1.497)	0.979	1.255 (0.559–2.816)	0.582
Voiding symptom subscore	1.076 (0.999–1.159)	0.052	1.058 (0.917–1.222)	0.438
Storage symptom subscore	1.030 (0.924–1.148)	0.592	1.021 (0.803–1.297)	0.868
Quality of life score	0.989 (0.739–1.324)	0.943	0.644 (0.269–1.541)	0.323
Q_{max}	0.955 (0.853–1.069)	0.422	0.877 (0.733–1.051)	0.155
Post void residual urine	0.999 (0.995–1.004)	0.731	1.002 (0.995–1.009)	0.622
Patients ≥70 years old				
BMI	1.164 (1.012–1.339)	0.033	1.004 (0.744–1.354)	0.981
DM(+)	0.719 (0.261–1.980)	0.523	0.784 (0.134–4.605)	0.788
HTN(+)	1.294 (0.575–2.910)	0.533	0.473 (0.107–2.092)	0.324
PSA	1.018 (0.926–1.118)	0.712	0.956 (0.793–1.153)	0.641
Prostate volume	1.022 (1.006–1.039)	0.007	1.031 (1.002–1.062)	0.039
BWT	1.697 (1.063–2.708)	0.027	-	
DWT	1.998 (1.179–3.385)	0.010	2.429 (0.934–6.318)	0.069
Voiding Symptom subscore	1.100 (1.019–1.189)	0.015	1.176 (0.961–1.439)	0.116
Storage Symptom subscore	1.131 (1.031–1.262)	0.028	1.144 (0.855–1.531)	0.364
Quality of life score	1.384 (0.976–1.963)	0.068	1.087 (0.505–2.339)	0.832
Q_{max}	0.904 (0.801–1.019)	0.098	0.791 (0.634–0.986)	0.037
Post void residual urine	1.001 (0.997–1.005)	0.627	1.006 (0.996–1.016)	0.236

Values are presented as odds ratio (95% confidence interval).
BOO, bladder outlet obstruction; BMI, body mass index; DM, diabetes mellitus; HTN, hypertension; PSA, prostate specific antigen; BWT, bladder wall thickness; DWT, detrusor wall thickness; Q_{max}, maximal flow rate.

66% negative predictive value, and 65% diagnostic accuracy. Meanwhile, in all patients, the classification by DWT ≥3 mm showed 43% sensitivity, 75% specificity, 55% positive predictive value, 63% negative predictive value, and 61% diagnostic accuracy for the diagnosis of BOO. In men aged 70 years or older, DWT ≥3 mm showed 49% sensitivity, 82% specificity, 63% positive predictive value, 71% negative predictive value, and 69% diagnostic accuracy (Table 4).

DISCUSSION

A recent review article about the BWT and DWT by

https://doi.org/10.4111/icu.20190376

Table 4. BOO index profiles according to BWT (4 mm) and DWT (3 mm)

Ultrasonographic features		BOO index		Total	p-value
		Obstructed	Unobstructed		
All patients					
BWT	<4 mm	54	87	141	<0.029
	≥4 mm	30	25	55	
		84	112	196	
DWT	<3 mm	48	83	131	<0.010
	≥3 mm	36	29	65	
		84	112	196	
Patients ≥70 years old					
BWT	<4 mm	27	52	79	0.033
	≥4 mm	12	8	20	
		39	60	99	
DWT	<3 mm	20	49	69	<0.001
	≥3 mm	19	11	30	
		39	60	99	

BOO, bladder outlet obstruction; BWT, bladder wall thickness; DWT, detrusor wall thickness.

Bright et al. [4] concluded that a positive relationship among BWT, DWT and the BOO index had been verified consistently, but a precise reference range was still not established. DWT might be influenced by various factors, especially those affecting bladder filling. Therefore, some researchers have recommended filling the bladder with more than 150 to 200 mL normal saline before measuring BWT and DWT [8-10]. However, assessing the bladder filling status in a real clinical practice setting is very difficult. Our opinion is that the easiest situation for the patient is to perform the transabdominal ultrasonography and to measure BWT and DWT by checking the post-void residual urine volume after uroflowmetry.

In the present study, the measured values of BWT and DWT were somewhat higher than those reported in previous studies [11,12], which could have resulted from differences in bladder filling status [13]. About 64.3% (126/196) of the patients had a post-void residual urine volume under 50 mL, whereas the men with residual urine volume ≥150 mL accounted for only 12.2% (24/196). BWT and DWT were relatively thicker in men with urine volumes under 50 mL than over 50 mL; however, the difference was not statistically significant (BWT: 3.5+1.1 mm vs. 3.3+1.1 mm, p=0.246; DWT: 2.6+0.9 mm vs. 2.4+0.9 mm, p=0.107). An additional study will be required for a larger population of patients with BOO when distributed into groups according to a residual urine volume.

The noted difference in BWT and DWT according to the age group was interesting. BWT and DWT were not statistically distinguishable in men aged less than 70 years, whereas BWT and DWT were significantly thicker in the obstruction group in men aged 70 years or older. Previous animal studies reporting that BOO led to hypertrophy of bladder [14,15] suggested that a gradual increase in BWT and DWT after BOO had occurred. Therefore, BWT and DWT could also be decreased when BOO was resolved after BPH surgery, as observed in our previous report [5]. BWT and DWT would also be a significant parameter in men who had suffered from obstructive symptoms for a long time.

More than 10 years have passed since the hypothesis was first suggested that BWT and DWT measurements could replace urodynamic studies, but a simple and precise measurement method for BWT and DWT determination has not been established. Oelke et al. [12,13] measured DWT during a filling cystometrogram, a part of the urodynamic study, and for that reason, they also reported the change in DWT according to the bladder filling volume. However, their measurement method was not appropriate for the practical application of BWT and DWT. In other words, if we had to measure the BWT and DWT during the urodynamic study for the confirmation of substitution of urodynamic study, this did not serve the purpose of reducing the need for the invasive urodynamic study; rather, it was just an interesting line of academic research. Another consideration was that artificial filling via a urethral catheter could affect the physiology of bladder, BWT and DWT when compared to natural filling. By all accounts, measurements of BWT and DWT during a check of the post-void residual urine volume after uroflowmetry could be practical and useful and would add no extra cost or time consumption for the patients.

In this study, we suggested values of BWT ≥4 mm and DWT ≥3 mm as cut-off values for the diagnosis of BOO. These values were determined based on a receiver operating characteristic curve and consideration of the convenience of clinical application. However, the diagnostic accuracy of BWT and DWT did not reach a dependable level, which might reflect a statistical problem because of the low number of subjects, especially in the older age group. The accuracy of urodynamic studies for the diagnosis of BOO should be discussed [16].

Although we used a prospectively collected BPH surgery database with original rationales, the study has some limitations. First, a relatively small number of patients were included in the subgroup analysis. In particular, the number of subjects with BOO was small, so this might have biased the statistical analysis. Second, although measuring BWT and DWT was performed under the standard urologic ultrasonographic guideline by a single experienced radiologist, the additional confirmation of the time-dependent and inter-observer stability during the examination should be included in the future study. It is impossible to conclude BOO based solely on BWT and DWT. Nonetheless, checking the bladder and measuring BWT and DWT via ultrasonography may be useful in clinical practice in the initial evaluation of BPH patients. As mentioned in the results part, because patients with the thicker BWT/DWT in the initial workup would have a higher chance to show BOO, this information might be helpful to decide the treatment plan.

CONCLUSIONS

BWT and DWT values were significantly associated with BOO in men aged 70 years or older. BWT and DWT therefore represent a useful non-invasive parameter for deciding management strategies in elderly men with symptomatic BPH. An appropriate measurement method should be established as soon as possible for further application of the relationship among BWT, DWT and BOO index.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

ACKNOWLEDGMENTS

This research was supported by the Korean Society for Urological Ultrasonography Grant 2015-01.

AUTHORS' CONTRIBUTIONS

Research conception and design: Juhyun Park and Hwancheol Son. Data acquisition: Juhyun Park, Jungyo Suh, Sangjun Yoo, Min Chul Cho, and Hwancheol Son. Statistical analysis: Juhyun Park, Sangjun Yoo, and Hwancheol Son. Data analysis and interpretation: Juhyun Park, Jungyo Suh, Sangjun Yoo, Min Chul Cho, and Hwancheol Son. Drafting of the manuscript: Juhyun Park and Hwancheol Son. Critical revision of the manuscript: Juhyun Park, Min Chul Cho, and Hwancheol Son. Obtaining funding: Hwancheol Son. Administrative, technical, or material support: Juhyun Park and Jungyo Suh. Supervision: Hwancheol Son. Approval of the final manuscript: Juhyun Park, Jungyo Suh, Sangjun Yoo, Min Chul Cho, and Hwancheol Son.

REFERENCES

1. Nitti VW. Pressure flow urodynamic studies: the gold standard for diagnosing bladder outlet obstruction. Rev Urol 2005;7(Suppl 6):S14-21.
2. Rosier PFWM, Schaefer W, Lose G, Goldman HB, Guralnick M, Eustice S, et al. International Continence Society Good Urodynamic Practices and Terms 2016: urodynamics, uroflowmetry, cystometry, and pressure-flow study. Neurourol Urodyn 2017;36:1243-60.
3. Porru D, Madeddu G, Campus G, Montisci I, Scarpa RM, Usai E. Evaluation of morbidity of multi-channel pressure-flow studies. Neurourol Urodyn 1999;18:647-52.
4. Bright E, Oelke M, Tubaro A, Abrams P. Ultrasound estimated bladder weight and measurement of bladder wall thickness--useful noninvasive methods for assessing the lower urinary tract? J Urol 2010;184:1847-54.
5. Lee H, Choo M, Kim M, Cho SY, Lee SB, Jeong H, et al. Changes in bladder wall thickness and detrusor wall thickness after surgical treatment of benign prostatic enlargement in patients with lower urinary tract symptoms: a preliminary report. Korean J Urol 2014;55:47-51.
6. De Nunzio C, Presicce F, Lombardo R, Carter S, Vicentini C, Tubaro A. Detrusor overactivity increases bladder wall thickness in male patients: a urodynamic multicenter cohort study. Neurourol Urodyn 2017;36:1616-21.
7. Presicce F, De Nunzio C, Gacci M, Finazzi AgròE, Tubaro A. Non-invasive ultrasound measurements in male patients with LUTS and benign prostatic obstruction: implication for diagnosis and treatment. Minerva Urol Nefrol 2017;69:220-33.
8. Franco G, De Nunzio C, Leonardo C, Tubaro A, Ciccariello M, De Dominicis C, et al. Ultrasound assessment of intravesical prostatic protrusion and detrusor wall thickness--new stan-

https://doi.org/10.4111/icu.20190376

dards for noninvasive bladder outlet obstruction diagnosis? J Urol 2010;183:2270-4.
9. Manieri C, Carter SS, Romano G, Trucchi A, Valenti M, Tubaro A. The diagnosis of bladder outlet obstruction in men by ultrasound measurement of bladder wall thickness. J Urol 1998;159:761-5.
10. Blatt AH, Titus J, Chan L. Ultrasound measurement of bladder wall thickness in the assessment of voiding dysfunction. J Urol 2008;179:2275-8; discussion 2278-9.
11. Kessler TM, Gerber R, Burkhard FC, Studer UE, Danuser H. Ultrasound assessment of detrusor thickness in men-can it predict bladder outlet obstruction and replace pressure flow study? J Urol 2006;175:2170-3.
12. Oelke M, Höfner K, Wiese B, Grünewald V, Jonas U. Increase in detrusor wall thickness indicates bladder outlet obstruction (BOO) in men. World J Urol 2002;19:443-52.
13. Oelke M, Höfner K, Jonas U, Ubbink D, de la Rosette J, Wijkstra H. Ultrasound measurement of detrusor wall thickness in healthy adults. Neurourol Urodyn 2006;25:308-17; discussion 318.
14. Saito M, Ohmura M, Kondo A. Effects of long-term partial outflow obstruction on bladder function in the rat. Neurourol Urodyn 1996;15:157-65.
15. Nielsen KK, Andersen CB, Petersen LK, Oxlund H, Nordling J. Morphological, stereological, and biochemical analysis of the mini-pig urinary bladder after chronic outflow obstruction and after recovery from obstruction. Neurourol Urodyn 1995;14:269-84.
16. MacLachlan LS, Rovner ES. Good urodynamic practice: keys to performing a quality UDS study. Urol Clin North Am 2014;41:363-73, vii.