Urethral Sphincter Morphology in Women With Detrusor Instability

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OBJECTIVE: To determine whether sonographic urethral sphincter morphology is different in patients with detrusor instability than in those with normal urodynamic testing.

METHODS: Patients from a population of women presenting for evaluation of urinary incontinence or pelvic organ prolapse underwent intraurethral ultrasonography before multichannel urodynamic testing. Maximal rhabdosphincter thickness, total urethral diameter, total urethral circumference, and longitudinal smooth muscle thickness, diameter, and circumference were measured. For patients with detrusor instability, the strength of the involuntary detrusor contraction and the bladder volume at its onset were recorded. These data were compared with information from history questionnaires and urodynamic evaluations.

RESULTS: The 17 patients with detrusor instability and 16 patients with normal urodynamic testing did not differ with respect to age, vaginal parity, race, weight, body mass index, prior continence surgery, or maximal total urethral closure pressure. Patients with detrusor instability, had decreased urethral longitudinal smooth muscle thickness (3.0 ± 0.9 mm vs 4.1 ± 0.7 mm, $P = .001$), total urethral diameter (18.0 ± 1.6 mm vs 19.4 ± 1.4 mm, $P = .01$), and total urethral circumference (5.65 ± 0.5 cm vs 6.1 ± 0.4 cm, $P = .012$) compared with those with normal urodynamic tests. A linear relationship between rhabdosphincter thickness and strength of involuntary detrusor contraction was observed ($r = .686$, $P = .002$).

CONCLUSION: Urethral sphincter morphology is different in patients with detrusor instability compared with those who have normal urodynamic tests. These findings provide an anatomic basis for the physiologic findings in patients with "urethrogenic" detrusor instability. (Obstet Gynecol 2002;99:63–8. © 2002 by the American College of Obstetricians and Gynecologists.)

Detrusor instability is the cause of urinary incontinence in 20–30% of women.[1] Differing theories about the pathophysiology of this disorder have been proposed. These include: 1) that detrusor instability results from an occult central or peripheral nerve disorder, or 2) that it is a primary disorder of detrusor smooth muscle.[2] Some researchers have suggested the term "urethrogenic" detrusor instability to describe reflex detrusor contractions that result from urine entering an incompetent urethra.[3–8] This "urethrogenic" theory has been supported by observations that patients with detrusor instability have significantly lower maximal urethral closure pressures on urethral pressure profilometry.[9] Some authors advocate bladder neck suspension for patients with detrusor instability and genuine stress incontinence to prevent urine from entering the urethra and activating the so-called urethrodetrusor facilitative reflex.[4,10–13]

Intraurethral ultrasonography has recently emerged as a valid test for evaluating the cross-sectional anatomy of the female urethra.[14–16] Images of both the urethral smooth and striated muscle layers correlate with cross-sectional histology from human female cadavers.[14,15] This technology has been used to study urethral sphincter morphology in stress-incontinent women and may provide insight into differences in sphincter morphology in women with detrusor instability.

The purpose of our study was to use intraurethral ultrasonography to compare urethral sphincter morphology in women with detrusor instability and those with normal urodynamic tests.

MATERIALS AND METHODS

To determine the clinical utility of this new radiologic modality for women with urinary incontinence, 130 consecutive patients underwent intraurethral ultrasonography. Urethral sphincter morphology in the stress-incontinent cohort has previously been compared with women who present with a normal urodynamic test.[17] Not all women who underwent urodynamic testing had symptoms of urinary incontinence. Some had prolapse of the posterior vaginal wall and underwent urodynamic testing with their prolapse reduced before surgery.

Intraurethral ultrasonography was performed before urodynamic testing in all patients. One investigator

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(MH) performed both evaluations in this ordered but unblinded fashion. Before evaluation, each patient completed a detailed urogynecologic history questionnaire. A physical examination included cotton swab testing with staging of any prolapse in the supine and standing position. Catheterized urine specimens were sent for culture, and all patients with positive results were treated with antibiotics before urodynamic testing. Patients with anterior vaginal wall prolapse to the introitus or beyond while seated in a Century Birthing Chair (Century Medical Equipment, Aurora, NE) were excluded from the study. Those whose urodynamic diagnosis included genuine stress urinary incontinence, genuine stress incontinence with coexistent detrusor instability, intrinsic urethral sphincter deficiency, decreased bladder compliance, or overflow incontinence, and all patients with known neurologic disease were excluded.

For urethral imaging, we used a 6.2 French, 12.5-mHz Sonicath intravascular ultrasound catheter (Microvasive, Boston Scientific, Natick, MA), which was connected to a B & K Model 3535 ultrasound scanning system (US Medical, Cincinnati, OH) with a Model 1880 Sonicath interface (US Medical). The Sonicath is a polyethylene device, which contains a miniaturized rotating ultrasound transducer enclosed within an acoustic housing at the distal end of the round-tipped sheath. A one-way valve at the end of the acoustic housing is punctured with a 27-gauge needle to fill it with 0.2–0.5 mL of sterile water, which provides a good acoustic medium for imaging. The catheter assembly houses a flexible drive cable that rotates the transducer when connected to the motored drive hub of the Sonicath interface. By rotating this transducer, the sound waves are transmitted radially, rendering 360° cross-sectional images of the urethra that are offset 10° from perpendicular.

At approximately 30 frames per second, real-time ultrasound images are projected onto the monitor for evaluation. These images may be recorded on videotape or captured as still images using any thermal print recorder.

For this study, intraurethral ultrasonography was performed as follows. The patient was placed in the supine position seated in a Century Birthing Chair (Century Medical Equipment). The bladder was emptied before each ultrasonographic evaluation to eliminate bladder volume as a potential confounder of the relationship between sphincter morphology and diagnosis. The ultrasound catheter was passed transurethrally into the bladder and then slowly withdrawn into the urethra at a rate of 1 mm/s using a urethral pressure profilometer. Residual urine in the bladder is hypoechoic on ultrasound. To standardize each evaluation, this hypoechoic image was kept at the bottom of the monitor screen corresponding to the dependent position urine occupies when evaluating a supine subject. The total urethral length was imaged before selecting a point of maximal rhabdosphincter thickness. At this point, the cross-sectional image was frozen and measured. The urethral rhabdosphincter and longitudinal smooth muscle layer thickness were measured in millimeters using ultrasound calipers. The total urethral and longitudinal smooth muscle diameters were measured along a line drawn through the center of the ultrasound transducer to calipers placed on the outer portion of each structure. Circumferences were calculated from the diameter measurements and expressed in centimeters.

After the intraurethral ultrasonography, each patient underwent a multichannel urodynamic evaluation, which included digitally subtracted retrograde filling urethrocystometry, static and dynamic cough urethral pressure profilometry at maximum cystometric capacity, pressure flow studies, and Valsalva leak-point pressure determinations. Each patient underwent a second standing cystometry with provocation including coughing and heel bouncing. Study participants with posterior vaginal wall support defects had their prolapse reduced with a Sims speculum taped to the perineum during their urodynamic evaluation. The specifics of the urodynamic evaluation have been previously described.[17]

Women with normal urodynamic testing were patients with no demonstrable urine leakage during urethrocystometry, dynamic cough urethral pressure profilometry, and Valsalva leak-point pressure determinations at 150 mL of bladder volume and maximum cystometric capacity in the standing position with and without the transurethral catheter in place. The diagnosis of detrusor instability was made when we identified involuntary phasic detrusor contractions during urethrocystometry or standing cystometry with provocation regardless of whether they were associated with urine leakage. In women with detrusor instability, the strength of the involuntary detrusor contraction in cm H_2O, and bladder volume at onset of detrusor instability were recorded.

Data from each patient's history, physical examination, intraurethral ultrasonography, and urodynamic evaluation were entered and analyzed using Statistical Package for the Social Sciences 9.0 (SPSS Inc., Chicago, IL). Separate variance Student *t* tests were used to compare age, vaginal parity, weight, body mass index (BMI), and maximal urethral closure pressure in women with detrusor instability and those with normal urodynamic testing. A χ^2 test for association with Yates correction and Fisher exact test was used to compare differences in prior continence surgery and race between the two

Table 1. Comparison of Demographic and Clinical Data in Women With Detrusor Instability and Normal Urodynamic Testing

Variable	Patients with detrusor instability	Normal urodynamic testing	*P*
Age (y)	50.4 ± 4.9	42.3 ± 1.2	.091
Vaginal parity	2.4 ± 1.7	2.3 ± 1.4	.908
Race			
White	15 (94%)	15 (88%)	
Black	0	2 (12%)	.226
Hispanic	1 (6%)	0	
Weight (lb)	160.3 ± 33.8	175.5 ± 36.8	.258
BMI (kg/m^2)	27.1 ± 4.4	30.1 ± 5.7	.145
Prior continence surgery	43.8%	31.3%	.465
Maximum urethral closure pressure (cm H_2O)	57.6 ± 28.4	74 ± 24.5	.142

Data are mean ± standard deviation.

groups. The Mann-Whitney *U* tests were used to compare differences in rhabdosphincter thickness, total urethral diameter, total urethral circumference, and longitudinal smooth muscle thickness, diameter, and circumference. Pearson correlation coefficients were calculated to examine the bivariate relationship between detrusor contraction strength and bladder volume at detrusor instability, with age and vaginal parity. Spearman correlation coefficients were calculated to examine the bivariate relationship between detrusor contraction strength and bladder volume at detrusor instability, with rhabdosphincter thickness, total urethral diameter, total urethral circumference and longitudinal smooth muscle thickness, diameter, and circumference as seen on intraurethral ultrasonography. *P* values less than .05 were considered significant. This study was reviewed and approved by the human studies committee at our institution.

RESULTS

All of the patients who underwent intraurethral ultrasonography had urodynamic testing. The urodynamic diagnoses of the 130 patients were as follows: 16 were normal (12.3%), 17 had detrusor instability (13.1%), 59 had genuine stress incontinence (45.4%), 18 had genuine stress incontinence with coexistent detrusor instability (13.8%), 15 had intrinsic sphincter deficiency (11.5%), three had decreased bladder compliance (2.3%), one had overflow incontinence (0.8%), and one chart was lost (0.8%). All patients with detrusor instability and normal urodynamic testing from the intraurethral ultrasonography cohort were selected for inclusion in the study: 17 with detrusor instability, and 16 with normal urodynamic testing.

The mean age of the study population was 46.5 ± 13.7. The mean vaginal parity was 2.4 ± 1.5. The mean weight and body mass index was 167.7 ± 35.5 pounds and 28.5 ± 1.5 kg/m^2, respectively. Of the women in the study population, 30 were white (90.9%), two were black (6.1%), and one was Hispanic (3.0%). Of the study participants, 37.5% had had prior continence surgery. The mean maximal urethral closure pressure was 68.1 ± 26.7 cm H_2O for the population as a whole.

The two study groups did not differ significantly with regard to age, vaginal parity, race, weight, BMI, prior continence surgery, or maximal urethral closure pressure (Table 1).

Differences in urethral sphincter morphology between women with detrusor instability and normal urodynamic testing are seen in Table 2. A significant difference in total urethral diameter (18.0 ± 1.6 vs 19.4 ± 1.4 mm, $P = .01$) and circumference (5.65 ± 0.5 vs 6.1 ± 0.4 cm, $P = .012$) was noted between the patients with detrusor instability and normal urodynamic testing. The difference in total urethral circumference can be anticipated as this value is calculated from the diameter measurement. Patients with detrusor instability had thinner urethral

Table 2. Comparison of Urethral Sphincter Morphologic Measurements in Women With Detrusor Instability and Normal Urodynamic Testing

Measurement	Patients with detrusor instability	Normal urodynamic testing	*P*
Rhabdosphincter thickness	3.5 ± 0.6 mm	3.5 ± 0.5 mm	.986
Total urethral diameter	18.0 ± 1.6 mm	19.4 ± 1.4 mm	.010
Total urethral circumference	5.65 ± 0.5 cm	6.1 ± 0.4 cm	.012
Longitudinal smooth muscle thickness	3.0 ± 0.9 mm	4.1 ± 0.7 mm	.001
Longitudinal smooth muscle diameter	12.5 ± 2.0 mm	13.7 ± 1.5 mm	.127
Longitudinal smooth muscle outer circumference	3.9 ± 0.6 cm	4.3 ± 0.5 cm	.217

Data are means ± standard deviation.

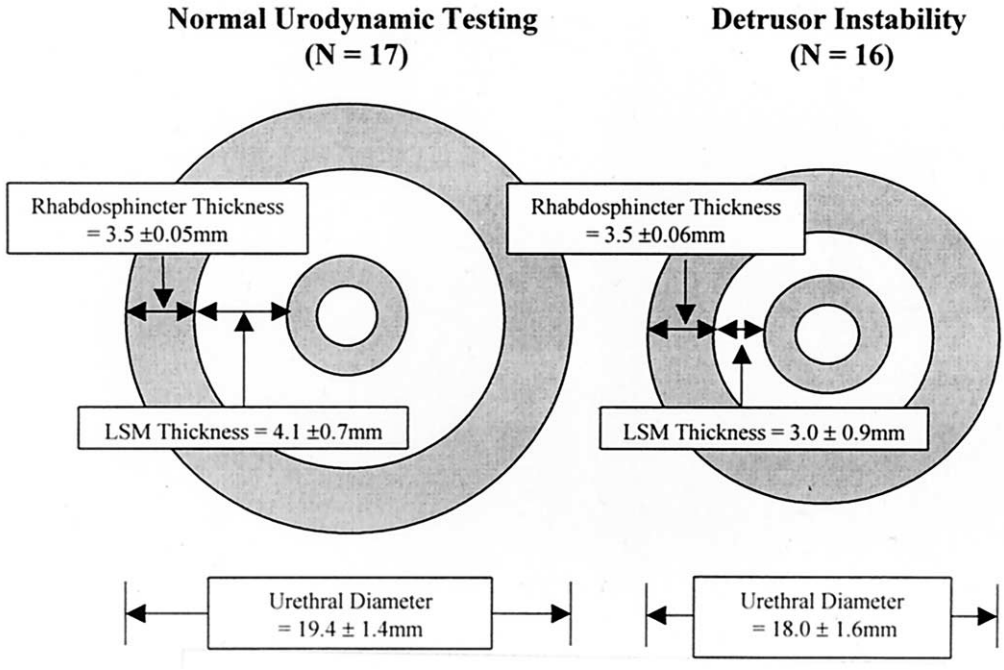

Figure 1. Cross-sectional differences in urethral sphincter morphology in women with detrusor instability and normal urodynamic testing.

Major. Detrussor Instability Sphincter Morphology. Obstet Gynecol 2002.

longitudinal smooth muscle layers (3.0 ± 0.9 vs 4.1 ± 0.7 mm, $P = .001$).

The decrease in total urethral diameter and therefore circumference is directly related to the decrease in longitudinal smooth muscle thickness because there was no difference in rhabdosphincter thickness between the two groups. The urethral lumen diameter is held constant by the ultrasound catheter, and previous studies have documented that the mucosal/submucosal connective tissue layer thickness does not differ.[15] With these parameters held constant, a decrease in the longitudinal smooth muscle thickness results in a decrease in total urethral diameter and subsequently, circumference (Figure 1).

Bladder volume at detrusor instability did not correlate with age, vaginal parity, or any sphincter measurement. Detrusor contraction strength did not correlate with age or vaginal parity. In women with detrusor instability, a linear relationship between involuntary detrusor contraction strength and rhabdosphincter thickness was observed ($r = .686$, $P = .002$) (Figure 2).

DISCUSSION

This study demonstrates a clear difference in urethral sphincter morphology between patients with detrusor instability and those with normal urodynamic testing. Women with detrusor instability had a smaller total urethral diameter and circumference as a result of a loss of longitudinal smooth muscle thickness. This suggests an anatomic reason for the physiologic findings in patients with "urethrogenic" detrusor instability.

In a previous study, we found a weak positive linear

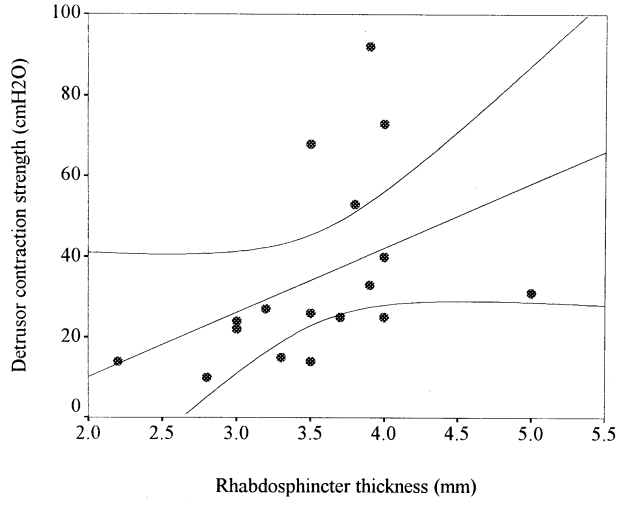

Figure 2. Correlation between rhabdosphincter thickness and involuntary detrusor contractions in women with detrusor instability.

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association between longitudinal smooth muscle thickness and urethral resistance, as measured by maximal urethral closure pressure.[17] A loss of longitudinal smooth muscle thickness could therefore result in a decrease in urethral resistance, allowing urine to enter the proximal bladder neck leading to a detrusor contraction. According to Mahoney et al,[5] when urine enters the proximal urethra, the urethrodetrusor facilitative reflex activates the sacral micturition center leading to "micturition hyperreflexia." However, this is unlikely to lead to overt detrusor instability and urine loss, unless the sacral micturition center is overfacilitated.

Overfacilitation of the sacral micturition center occurs in some multiparous women, because of underactivity of the perineodetrusor inhibitory reflex and overactivity of the perineobulbar detrusor facilitative reflex associated with muscle weakness and relaxation of the pelvic floor and perineum.[5] Bump concluded that some women will exhibit detrusor activity in response to perfusion of fluid through the urethra, which he attributed to a failure of voluntary cortical suppression of the micturition reflex.[18] During an involuntary detrusor contraction on filling cystometry, some nulliparous women remain continent by actively contracting their pelvic floor musculature preventing overfacilitation of the sacral micturition center.

In patients with detrusor instability we identified a positive correlation between rhabdosphincter thickness and detrusor contraction pressure. In a previous study,[17] we also found a weak positive linear association between rhabdosphincter thickness and urethral resistance, as measured by maximal urethral closure pressure. Thus, when the sacral micturition center is overfacilitated, the activated detrusor must contract more strongly against increased urethral resistance. Clinically, when urethral resistance is too high, we characterize this pathophysiologic finding as "obstruction" in the pressure flow relationship during instrumented voiding studies. This finding provides support for the concept of detrusor instability as a premature activation of the normal micturition reflex.

There are several limitations to our study. Selection bias may have been introduced because of the retrospective nature of our study. Including all patients with detrusor instability and normal urodynamic testing from the intraurethral ultrasonography cohort minimized this bias. Patients with normal urodynamic testing in our study may also differ from age- and parity-matched asymptomatic controls.

Before the urodynamic diagnosis, all ultrasound measurements were obtained by one of the investigators (MH). Despite the ordered evaluation, this investigator (MH) was not blinded to patient symptoms because he was responsible for the clinical care of each patient.

Artifact may be produced when a thick ultrasound catheter is introduced through a small caliber urethral lumen causing compression of the urethral muscular layers. According to Schaer et al,[14] the ultrasound probe changes the appearance of the urethral tissues as smooth sphincter muscles and mucosa are changed from oval (histologic) to circular (ultrasound) layers. They felt that compression of the urethral tissues also occurs; however, for clinical purposes and for the measurement of muscle layer thickness, this reproducible variation of the anatomy is of minor importance. In our study, urethral lumen calibration was not performed before introduction of the intraluminal ultrasound probe. Therefore, the caliber of the urethral lumen was unknown to the investigators, making it less likely that an observer bias towards smaller urethral lumen calibers in the detrusor instability group was introduced.

Because black and Hispanic women are underrepresented in our study population, it is not possible to generalize our findings beyond white women. Although the differences in urethral sphincter morphology are statistically significant, it is unclear if they are clinically significant. Millimeter differences in morphologic measurements may not account for the functional differences in women with detrusor instability compared with women with normal urodynamic testing. Because of the cross-sectional nature of our study design, we cannot establish urethral sphincter morphologic differences as a cause for detrusor instability. In fact, urethral sphincter morphologic differences may be the result of bladder overactivity rather than its cause.

Conclusions drawn from this study should be considered preliminary based on its small sample size. We were unable to detect a difference in maximal urethral closure pressure between our two groups. However, our power to detect such differences was only 41%. Because our detrusor instability group had thinner urethral longitudinal smooth muscle layers and lower maximal urethral closure pressures, the present study supports our previous study, which found a weak positive linear association between these two variables.[17] We could not correlate urethral longitudinal smooth muscle or rhabdosphincter thickness with maximal urethral closure pressure in patients with detrusor instability because their involuntary contractions prevented us from completing urethral pressure profilometry in nine of 17 patients.

It is unlikely that the age difference in our two groups confounded the association between urethral sphincter morphology and diagnosis because a post hoc power analysis revealed that we had only a 1% probability (99%

power) of making a random error by stating that the ages in the two groups were similar.

We recognize that some of the patients classified as having normal urodynamic testing may have had detrusor instability, given the 40% false-negative rate of cystometry reported in the literature.[18] We minimized this false-negative rate by provocation during standing cystometry. Ambulatory urodynamic testing was not considered due to its expense and high false-positive rate.[18]

Finally, this study raises several questions. First, does urethral sphincter morphology differ in *all* patients with detrusor instability, or have we identified a subset of patients with "urethrogenic" detrusor instability? Do these sphincter differences support research that identifies a subgroup of patients with detrusor instability who have coexistent urethral instability, or precontraction urethral relaxation? These could be patients who do not respond to anticholinergic medications, yet respond to bladder neck suspension, pelvic muscle exercises, or alpha agonist therapy.[4–6,8,19]

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