Perineal Ultrasound Evaluation of Dysfunctional Voiding in Women With Recurrent Urinary Tract Infections

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Purpose: We used urodynamics and perineal ultrasound to assess the function and morphology of the urethral sphincter and detrusor muscle in the evaluation of dysfunctional voiding in female patients with recurrent urinary tract infections.

Materials and Methods: Patients selected for study purposes completed the American Urological Association Symptom Index and underwent multichannel video urodynamics and perineal ultrasound to evaluate urethral sphincter volume and detrusor thickness.

Results: Of the 337 patients referred to our institution for recurrent urinary tract infections 166 were finally evaluated, including group 1—65 women with recurrent urinary tract infections and dysfunctional voiding, group 2—77 with recurrent urinary tract infections without dysfunctional voiding and group 3—24 healthy controls. Storage and emptying symptoms were recorded in 87.6% and 84.6% of group 1 patients, respectively. Opening and maximum flow detrusor pressure significantly correlated with urethral sphincter volume, and mean and maximum urethral closure pressure and detrusor thickness correlated with urethral sphincter volume. Dysfunctional voiding could be diagnosed by ultrasound when an increase in detrusor thickness and striated sphincter volume were observed. A threshold sphincter volume of 1.96 cm³ had 100% sensitivity and 63.2% specificity, and a threshold detrusor thickness of 4.95 mm had 100% sensitivity and 85.4% specificity for identifying patients with dysfunctional voiding.

Conclusions: We think that perineal ultrasound is useful in the evaluation of dysfunctional voiding in women with recurrent urinary tract infections.

Key Words: bladder, urinary tract infections, urodynamics, ultrasonography, voiding disorders

Recurrent UTIs are common in young women. There is no satisfactory theory to explain the predisposition of young healthy women with a normal urinary tract to recurrent UTIs but it could be the result of a combination of factors.

Diagnostic evaluation in women with recurrent UTIs often requires diagnostic imaging to uncover anatomical abnormalities, although most patients have a normal urinary tract on conventional investigation.

Recurrent UTIs may occur in up to 42% in patients with dysfunctional voiding. It is an abnormality of bladder emptying in neurologically normal individuals in whom there is increased external sphincter activity during voluntary voiding and it is thought to be a learned behavior. There are reports of this condition in children but much less has been written on adults.

To date standard urodynamic investigation has been an important tool for assessing lower urinary tract symptoms. Ultrasound has recently been used to evaluate urethrovaginal junction anatomy and bladder neck mobility to study stress urinary incontinence and assess urethral sphincter morphology and bladder wall thickness. We used urodynamics and perineal ultrasound to assess the function and morphology of the urethral sphincter and detrusor muscle in the evaluation of dysfunctional voiding in female patients with recurrent UTIs.

MATERIALS AND METHODS

A prospective study was done at our institution between 2003 and 2006. The study population comprised women referred to our department with more than a 3-year history of recurrent UTIs with at least 3 or more symptomatic episodes during a 12-month period and the diagnosis of UTI been made using clean catch urine specimens sent for urinalysis and culture. The population included only nulliparous patients younger than 40 years without genital prolapse, previous surgery for incontinence or other pelvic procedures, or behavioral causes of recurrent UTIs, such as low water intake, postponed micturition, bowel problems or sexual intercourse. Also, 24 healthy volunteers, that is patients who did not report any lower urinary tract symptoms and were referred to a general practitioner for upper urinary tract pathology, were included in the study.

All patients provided informed consent to adhere to the study protocol. They provided a history and underwent physical examination, abdominal ultrasound, cystoscopy and neurological investigation as necessary. Those with

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morphological abnormalities and/or underlying neurological disease were excluded from study.

The selected patients completed the AUASI before further testing. Multichannel video urodynamic investigation was performed in all patients by 1 operator (DM) according to International Continence Society criteria using a Duet® Multi-P. Patients had negative urine cultures at the time of investigation or antibiotic treatment was started at least 10 days before urodynamics in those with positive urine cultures. Electromyography of the pelvic floor was performed at the level of the pubococcygeal muscles, as previously described. Simultaneous fluoroscopic images were obtained. The fill rate was 20 ml per minute with x-ray contrast material. Attention was given to the fluoroscopic appearance of the bladder outlet during voiding, including the bladder neck, and urethral and external sphincters. Urethral pressure profilometry was performed using the perfusion catheter technique with a 7Fr urethral catheter.

Patients with anatomical abnormalities were excluded from further investigations. The others were sent for perineal ultrasound at the same session.

Sonographic examination using an Astro 256 machine (Hitachi Medical Corp., Tokyo, Japan) was performed in all patients by 3 independent examiners with the patients supine using the translabial approach with a 3.5 MHz sector probe and the introital approach with a 6.5 MHz end fire endovaginal probe. The posterior urethrovesical angle, proximal pubo-urethral distance and urethral inclination angle were calculated. The thickness of the bladder detrusor wall was measured at the bladder dome via suprapubic perfusion catheter technique with a 7Fr urethral catheter.

Patients with anatomical abnormalities were excluded from further investigations. The others were sent for perineal ultrasound at the same session.

Urethral sphincter volume was measured using a 7.5 MHz transvaginal ultrasound probe with volume calculated using the formula for the volume of a cylinder, as described previously.

All assessments were done independently and consecutively by 3 operators. Ultrasound in every patient was performed by operator 1, who knew the patient condition, and by 2 subsequent operators who were blinded to patient history. Each operator performed 2 repeat measurements of each parameter assessed and printed them on film, so that each operator was blinded to the values of the assessment performed by the others. Assessment of each ultrasound parameter was later agreed on by the 3 operators.

Collected data were analyzed by the Kolmogorov-Smirnov test for normality, ANOVA and the Bonferroni post hoc test for normality, ANOVA and the Bonferroni post hoc test for differences in symptom score, and urodynamic and ultrasound measurement results were analyzed by the Wilcoxon signed rank test. The average of the 2 findings obtained by the 3 operators for each ultrasound parameter was used to analyze interobserver differences by the Friedman test. The mean value of measurements obtained by the 3 operators was used as a single measurement of each ultrasound parameter. Evaluation of the ultrasound parameter cutoff for diagnosing dysfunctional voiding was performed by ROC analysis with 2-sided p <0.05 considered statistically significant. Statistical analysis was performed using SPSS® 15.0 software.

**RESULTS**

A total of 337 patients were referred to our institution for recurrent UTIs during the study period, including 142 who fulfilled the selection criteria and were enrolled. To analyze perineal activity we divided the patients into 2 groups, including those with normal and those with increased electromyographic activity during voiding. A control group of patients without recurrent UTIs and with normal perineal activity was also considered. The diagnosis of dysfunctional voiding was made according to Carlson et al with increased external sphincter activity during voiding recorded on multichannel video urodynamics.

Overall 166 patients were evaluated, including group 1—65 women 17 to 31 years old (mean age 23.1) with recurrent UTIs and dysfunctional voiding, group 2—77, 15 to 33 years old (mean age 25.2), with recurrent UTIs and normal perineal activity during voiding, and group 3—24 healthy controls 17 to 29 years old (mean age 21.8).

**Urodynamics**

Patients assigned to groups 1 to 3 had a mean ± SD opening detrusor pressure of 53.8 ± 26, 7 ± 4 and 5 ± 4 cm H2O, and a detrusor pressure at maximum flow of 41.5 ± 16, 6 ± 4 and 5 ± 3 cm H2O, respectively (each p <0.05). There were no statistically significant differences among groups 1 to 3 when considering the mean flow rate (15.25 ± 6.4, 21.5 ± 7 and 24.2 ± 6 ml per second), flow time (25 ± 7, 16 ± 4 and 14 ± 4 seconds), voiding volume (475 ± 119, 572 ± 108 and 597 ± 99 ml) and post-void residual volume (57 ± 32, 10 ± 5 and 12 ± 4 ml, respectively). However, the voiding pattern was abnormal in 57 group 1 patients (87.6%) compared to that in groups 2 and 3. In group 1 detrusor overactivity was detected in 53 patients (81.5%) and impaired compliance was noted in 36 (55.3%). Urinary incontinence was noted during provocative maneuvers in 5 group 1 patients (7.6%) and in 2 in group 2 (2.5%) (table 1).

Obstruction according to Blaivas and Groutz was diagnosed in all group 1 patients. In that group 52 patients (80%)

| Table 1. Significant urodynamic and ultrasound measurement results |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                | Mean ± SD Group 1 | Mean ± SD Group 2 | Mean ± SD Group 3 | p Value (group 1 vs 2) |
| Opening detrusor pressure (cm H2O) | 53.8 ± 26        | 7 ± 4            | 5 ± 4            | 0.029          |
| Detrusor pressure at max flow (cm H2O) | 41.5 ± 16       | 6 ± 4            | 5 ± 3            | 0.043          |
| Urethral closure pressure (cm H2O) | 93.2 ± 19        | 56.6 ± 12        | 64.5 ± 11        | 0.043          |
| Max urethral closure pressure (cm H2O) | 118 ± 25.3       | 69.7 ± 19.3      | 75.7 ± 18.5      | 0.037          |
| Max urethral sphincter vol (cm³) | 2.87 ± 0.41      | 1.77 ± 0.62      | 1.61 ± 0.32      | <0.001         |
| Detrusor thickness (mm)     | 7.83 ± 0.89      | 3.81 ± 1.1       | 3.92 ± 1.8       | <0.001         |
had straining during voiding compared to none in groups 2 and 3.

On fluoroscopy a dilated urethra proximal to the urethral sphincter was observed in 32 group 1 patients (49.2%) and a lack of bladder neck funneling was observed in 11 (16.9%). These findings did not appear in groups 2 and 3.

Mean and maximum urethral closure pressure was significantly increased in group 1 patients (93.2 ± 19 cm H2O and 118 ± 25.3) compared to that in group 2 (56.6 ± 12 and 69.7 ± 19.3 cm H2O) and group 3 (64.5 ± 11 and 75.7 ± 18.5 cm H2O, respectively, p < 0.05, table 1).

**Symptom Score**

Storage symptoms, consisting mainly of frequency and urgency, were recorded in 73 of 142 patients (51.4%). Emptying symptoms, consisting mainly of decreased force of stream, hesitance, the need to strain and a feeling of incomplete bladder emptying, were observed in 63 patients (44.3%).

Of patients with storage symptoms 56 (87.6%) were in group 1 with dysfunctional voiding and 17 (26.1%) were in group 2. Of patients with emptying symptoms 55 (84.6%) were in group 1 with dysfunctional voiding and 17 (26.1%) were in group 2. Of patients with emptying symptoms 55 (84.6%) were in group 1 with dysfunctional voiding and 17 (26.1%) were in group 2. The differences were statistically significant in groups 2 and 3.

**Ultrasound**

As assessed by perineal ultrasound, urethral sphincter volume was 0.8 to 5 cm³. The transverse cross-section aspect of the urethra at ultrasound was also evaluated.

We observed that maximum urethral sphincter volume was significantly increased in group 1 patients compared to that in groups 2 and 3 (2.87 ± 0.41 vs 1.77 ± 0.62 and 1.61 ± 0.32 cm³, respectively, group 1 vs 2 p < 0.001, table 1). Abnormal findings on ultrasound included thickening of individual rings, hazy contours and a change in echogenic texture with loss of the characteristic 4-ring appearance. These findings were observed only in group 1 patients (fig. 1).

As assessed by suprapubic ultrasound, detrusor wall thickness was 2.2 to 9.3 mm. We also observed that the detrusor was significantly thicker in group 1 patients compared to that in groups 2 and 3 (7.83 ± 0.8 vs 3.81 ± 1.1 and 3.92 ± 1.8 mm, respectively, group 1 vs 2 p < 0.001, table 1 and fig. 2).

The diagnosis of urethral hypermobility was confirmed on ultrasound in 7 patients, including 5 in group 1 and 2 in group 2, by evaluating the posterior urethrovessical angle, the dynamic angle of urethral inclination and the proximal pubo-urethral distance, as described previously.7

**Table 2. Patient characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. pts.</td>
<td>65</td>
<td>77</td>
<td>24</td>
<td>0.23</td>
</tr>
<tr>
<td>Mean age</td>
<td>23.1</td>
<td>25.2</td>
<td>21.8</td>
<td>0.05</td>
</tr>
<tr>
<td>% AUASI symptoms:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>87.6%</td>
<td>26.1%</td>
<td>0%</td>
<td>0.04</td>
</tr>
<tr>
<td>Emptying</td>
<td>84.6%</td>
<td>12.3%</td>
<td>0%</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Differences in the AUASI storage and emptying domains was statistically significant (p < 0.05).

Opening detrusor pressure and detrusor pressure at maximum flow significantly correlated with urethral sphincter volume (rho = 0.580, p = 0.001 and rho = 0.495, p = 0.001, respectively). Mean and maximum urethral closure pressure correlated with urethral sphincter volume (rho = 0.485, p = 0.009 and rho = 0.530, p = 0.005, respectively). Detrusor thickness correlated with urethral sphincter volume (rho = 0.457, p = 0.001).

ROC analysis showed that to identify a patient with dysfunctional voiding a sphincter volume threshold of 1.94 cm³ had 100% sensitivity and 63.2% specificity (AUC 0.925, p <0.001, fig. 3), and a detrusor thickness threshold of 4.95 mm had 100% sensitivity and 85.4% specificity (AUC 0.995, p <0.001). At these cutoff values in 56.9% of the patients with dysfunctional voiding the values of these 2 ultrasound parameters were above the threshold level.

**DISCUSSION**

The prevalence of dysfunctional voiding in adults is unknown but it has been suggested that this disorder is more common than commonly recognized.17 It has been referred to by various terms, including pseudodyssynergia, external sphincter spasticity and nonrelaxing external urethral sphincter.4 There are several theories of why dysfunctional voiding occurs in adults. It could be a learned behavior in response to adverse pelvic conditions such as infection, inflammation or trauma, it could be the result of voluntary withholding of urination in individuals who are away from

![Fig. 1. Thickening of urethra (URETRA) with loss of contrast definition of anatomical components, absent recognition of 4-ring structure of different echogenicity and increased sphincter volume in woman with dysfunctional voiding.](image1)

![Fig. 2. Bladder wall thickness increased to 9.3 mm in 38-year-old woman with dysfunctional voiding.](image2)
The association of dysfunctional voiding with recurrent UTIs has been documented. Dysfunctional voiding can disrupt the laminar urinary flow through the urethra, causing UTIs as bacteria are transferred back from meatus to bladder as a result of sudden unanticipated detrusor contractility.

We did not perform concentric needle electromyography of the striated urethral sphincter. It is not commonly performed since it requires special equipment, technical expertise and an experienced investigator. Electromyography of the pubococcygeal muscles together with recordings of other urodynamic variables is helpful for revealing inappropriate electromyography activity during micturition.

Many groups have studied urethral sphincter volume and detrusor wall thickness in women with urinary incontinence, urinary retention and detrusor instability. To our knowledge our study describes a novel approach to the investigation of recurrent UTIs in women. We performed videourodynamic investigation in the first instance, thereby diagnosing dysfunctional voiding. In our study according to our analysis of opening/maximum flow detrusor pressure and mean/maximum urethral closure pressure patients with recurrent UTIs associated with dysfunctional voiding had obstruction. Similarly by analyzing detrusor thickness and striated sphincter volume on ultrasound we could diagnose obstruction. We found positive correlations between opening/maximum flow detrusor pressure and urethral sphincter volume, between mean/maximum urethral closure pressure and urethral sphincter volume, and between detrusor thickness and urethral sphincter volume in patients with recurrent UTIs associated with dysfunctional voiding. As a consequence of dysfunctional voiding, the increased urethral sphincter volume could be the cause of functional obstruction.

Therefore, based on our experience dysfunctional voiding can be suspected on ultrasound in women with recurrent UTIs when an increase in detrusor thickness and striated sphincter volume is observed. Data derived from the ROC curves about the cutoff values for urethral sphincter volume and detrusor thickness allow us to propose perineal ultrasound as a first line diagnostic approach in the evaluation of dysfunctional voiding in women with recurrent UTIs.

CONCLUSIONS

We think that a first line approach in young nulliparous women with recurrent UTIs can be done by flow electromyography and by perineal ultrasound. In our experience these investigations are able to select patients with dysfunctional voiding. Therefore, multichannel videourodynamic can represent a second line diagnostic approach in select patients.

Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tr>
<td>AUASI</td>
<td>American Urological Association symptom index</td>
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<tr>
<td>UTI</td>
<td>urinary tract infection</td>
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REFERENCES


