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ORIGINAL ARTICLE

# The impact of multichannel urodynamics upon treatment recommendations for female urinary incontinence

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**Abstract** The aim of this study was to evaluate whether multichannel urodynamic testing changes a physician's treatment recommendations when managing women with urinary incontinence. In this prospective reader study, four fellowship-trained urogynecologists reviewed 39 abstracted cases of urinary incontinence on two occasions: first without and subsequently with urodynamic data. Treatment recommendations were made for each case after each review. The probability of urodynamic data modifying treatment recommendations was estimated for each reader and for the population of readers using a random effects logistic regression to account for reader variability. The overall probability that urodynamic data would change treatment was 26.9% (95% confidence interval (CI), 18.6%, 37.2%) for medical treatments and 45.5% (95% CI, 37.8%, 53.4%) for surgical treatments. Reader-to-reader differences accounted for 3% and <1% of the total variance for medical and surgical treatments, respectively. Multichannel urodynamic evaluations are significantly associated with changes in medical and surgical treatment recommendations in a referral population.

**Keywords** Female · Urinary incontinence · Urodynamics

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## Introduction

Urinary incontinence affects 12–55% of all women [10], resulting in annual direct costs of $12.4 billion in the US [16]. The evaluation of female urinary incontinence involves a focused history and physical and may involve a voiding diary, simple cystometry, or complex multichannel urodynamics. The role of multichannel urodynamics in the evaluation of incontinence is still unclear. Studies have shown that multichannel urodynamics can be reliably interpreted [17] and improve the accuracy of diagnosing specific types of urinary incontinence [3, 6, 9, 12, 15], but data clarifying their role in the development of treatment plans or showing improvement in patient outcomes are currently insufficient [5]. If urodynamics are a useful diagnostic tool, then their use will result in modified treatment recommendations for a significant number of cases.

Urodynamics can be used to help counsel patients and to guide treatment plans. For instance, patients who void with a weak or absent detrusor contraction are at an increased risk of postoperative urinary retention after a pubovaginal sling [7] and patients with a low maximum urethral closure pressure are more likely to have persistent stress incontinence following a transobturator versus a retropubic midurethral sling [8]. As these scenarios indicate, the function of the urethral sphincter and detrusor muscle may affect the decision process when implementing a treatment plan, as well as influencing the counseling of patients on expectations and outcomes.

On the other hand, a significant amount of objective data can be obtained through a basic office assessment,

including simple cystometry. Many recommend a more selective role for complex urodynamics [13, 14]. The benefits of the urodynamic evaluation should outweigh the risks, which include time, cost, invasiveness, discomfort for the patient, and the risk of an iatrogenic urinary tract infection.

The primary aim of this study was to evaluate whether multichannel urodynamic testing, in addition to a urogynecologic history and physical, changes the treatment recommendations for women with urinary incontinence. Secondary aims were (1) to estimate whether urodynamics change the diagnosis, (2) to identify any urodynamic parameters associated with changes in treatment recommendations, (3) to evaluate whether treatment changes after the addition of urodynamics are limited to complex patients, and (4) to evaluate if the perceived usefulness of urodynamics was associated with treatment changes.

## Materials and methods

This is a prospective reader study involving four fellowship-trained urogynecologists. Forty cases were selected from women referred to our tertiary-care medical center with a chief complaint of urinary incontinence; one case was compiled incorrectly and subsequently disregarded, leaving a total of 39 cases. Institutional Review Board approval was obtained before chart review began. Inclusion criteria for the cases were women presenting with a chief complaint of urinary incontinence and who underwent multichannel urodynamic evaluation at our division between January 2003 and November 2005. Exclusion criteria were extra-urethral incontinence, subjects unable to complete a urodynamic evaluation, and those with poor-quality urodynamics or an incomplete history and physical. Cases were systematically sampled (every 10th chart) from alphabetized office charts.

Deidentified, abstracted clinical information was compiled from the chart (RMW) into a standardized format. This included patient age rounded to the nearest 5 years, chief complaint, history of present illness, past medical and surgical history, current medications, and a physical exam. Pertinent details regarding symptoms of stress and urge incontinence, situational or aggravating factors, urgency, frequency of voids, nocturia, pad use, postvoid urgency or fullness, double voiding, crede or splinting maneuvers, hesitancy, presence of a weak stream, dysuria, hematuria, frequent urinary tract infections, and beverage consumption were compiled and presented in a standardized fashion. When present, a bladder diary was included. Abstracted physical exam data included vaginal atrophy, the Pelvic Organ Prolapse Quantification [2] exam if prolapse was present, pelvic floor muscle function quantified on a four-point scale, urethral hypermobility measured by the Q-tip test, an empty cough stress test, and a catheterized postvoid residual. If the subject complained of stress incontinence and the empty cough stress test was negative, then the cough stress test was repeated after artificially filling to 200–300 $cm^3$. Detrusor contractions during retrograde filling were only noted if they significantly interfered with bladder filling. Not all cases had information regarding urethral hypermobility or strength of the Kegel squeeze. All terminology used conforms to the standards recommended by the International Continence Society [1].

Complex multichannel urodynamic testing was performed using a Medtronic Duet® Logic (Medtronic, Skovlunde, Denmark), dual-sensor T-DOC Air-charged urethral catheters and T-DOC air-charged abdominal sensors (T-DOC Co., LLC, Wilmington, DE, USA). All procedures were done in a sitting erect position in a Century birthing chair (Century Manufacturing Co., Tampa, FL, USA), with room-temperature sterile water. The filling rate was 50 $cm^3$/min unless this provoked urinary urgency. Abdominal leak point pressures were measured at 200 $cm^3$, with the urethral catheter in place, unless otherwise specified. The abdominal pressure transducer was placed rectally. Prolapse to or beyond the hymen was reduced using scopettes, a monovalve speculum, or a pessary and this information was provided to the reviewers. Provocative maneuvers, including water stimulation and cough, were used in an effort to provoke detrusor overactivity. Urethral pressure profilometry was performed using a mechanical puller at a rate of 1 mm/s. Both static and dynamic profiles were performed at cystometric capacity. Recorded urodynamic parameters in addition to the urodynamic tracings were from the uroflowmetry (voided volume, postvoid residual, maximal flow rate, voiding time), cystometrogram (first sensation, first desire to void, capacity, fill rate, detrusor overactivity, detrusor overactivity incontinence, urodynamic stress incontinence, abdominal leak point pressure at 200 $cm^3$) and urethral pressure profilometry. Any pertinent documentation regarding sensory urgency or leakage during testing was included.

The four physician readers (BSH, VWS, CRR, DLM) reviewed each case on two occasions: first without and subsequently with urodynamic data, separated by a 2-week "washout" period between reviews. The order of the cases was randomized for each reviewer and each round of evaluations. All randomization was performed using a computerized random number generator. Fictitious "patient" names were attached to each case and changed with each round of reviews to minimize reader recollection of the cases. Reviewers selected the following diagnoses as being present, absent, or indeterminate based on history and physical examination alone: stress incontinence, urge incontinence, incomplete bladder emptying, chronic reten-

**Table 1** Treatment options

| Medical treatments | Surgical treatments | Conservative treatments |
|---|---|---|
| Imipramine | Retropubic midurethral sling | Decreased water and/or caffeine intake |
| Alpha-agonist | Transobturator midurethral sling | Physical therapy |
| Anticholinergic | Burch retropubic urethropexy | Incontinence ring–dish |
| Duloxetine | Traditional suburethral sling | Timed voids |
| Topical estrogen | Urethral bulking agent | Intermittent self-catheterization |
| Bethanechol | Sacral neuromodulation/percutaneous tibial nerve stimulation | Bedside commode |
| None | None | Expectant management |
| | | None |

Physician readers chose one from each category

tion of urine, and functional incontinence. For the analysis, mixed incontinence was defined as having both stress and urge incontinence present. When the urodynamic data were included, two additional diagnoses were available: intrinsic sphincter deficiency and detrusor overactivity; these diagnoses were based on the clinical judgment of the physician reader and no standard definition was used. There were three categories of treatment options (medical, surgical, and conservative) and reviewers could select none or one treatment in each category (see Table 1). The same selection of treatments was available for the cases with and without urodynamics. The physician readers were asked to select the treatments they felt were most appropriate given the information provided. Visual analog scales (VAS) were completed following each case. The exact questions asked are shown in Table 2.

### Statistical considerations

The primary aim was to estimate the probability that treatment recommendations changed with the addition of a urodynamic evaluation. We estimated this probability for each reader and for all readers combined. Exact binomial confidence intervals were used for reader-specific probabilities. A random effects logistic regression estimated the overall probability of a change in management while accounting for physician-to-physician variability and the correlation in readings that arise when two independent physicians read the same case. Robust standard errors were employed where appropriate. Covariates for case-specific characteristics (positive–negative cough stress test, maximum urethral closure pressure, detrusor overactivity, abdominal leak point pressure, interrupted voiding pattern, postvoid residual values, and flow rate) were explored for any potential effect on the probability of change in the logistic regression. Demographics and case characteristics are reported.

To assess intrareader reliability, each reviewer reevaluated 20 of the original 39 cases 3 months after initial data were collected (ten with and ten without urodynamics). Urodynamic parameters were analyzed for their impact on changes in the treatment recommendations and diagnosis.

It was projected that four readers each evaluating 40 abstracted cases would provide sufficient power and precision to estimate the probability that urodynamics will change the treatment recommendations. For a single reader, 40 cases provides 83% power to reject the null hypothesis that the probability of change is 5% or less (here, we use 5% instead of zero to conservatively account for any background treatment fluctuation), with a two-sided, 5%-sized test when the alternative hypothesis is 20%. Moreover, a 95% confidence interval will have a margin of error of 12.5% when the estimated proportion of change is 20%. For testing the average change in the pooled data, the power under the above-mentioned conditions is over 99% and the margin of error in a 95% confidence intervals drops to 6%, when the reader's assessments are assumed to be independent. Data analysis was performed with Stata SE 9.2.

## Results

Demographics of the 39 included women are presented in Table 3 along with the subjective complaints and objective findings. The mean age was 57 years (range 20–90 years);

**Table 2** Questions accompanied by visual analog scales

| Following cases without urodynamics[a] | Following cases with urodynamics[a] |
|---|---|
| Do you feel that the addition of urodynamics would be helpful in forming a treatment plan for this patient? | Do you feel that the addition of urodynamics helped you make a diagnosis? |
| | Do you feel that the addition of urodynamics helped you form a treatment plan? (i.e., did the additional information assist you in forming a treatment plan) |
| | Do you feel that the addition of urodynamics improved your treatment plan? (i.e., is your treatment plan better as a result of the information provided by the urodynamics) |

[a] VAS were filled out following each case

**Table 3** Demographics, subjective and objective descriptors of the clinical cases

| Demographics and case characteristics | Number ($n$=39) |
|---|---|
| Mean age (years) | 57 (range 20–90) |
| Median parity | 2 (range 0–7) |
| Menopausal | 24 (61.5%) |
| Prior hysterectomy | 18 (46.2%) |
| Prior oophorectomy | 10 (25.6%) |
| Prior anti-incontinence surgery | 5 (12.8%) |
| Prior surgery for pelvic organ prolapse | 3 (7.7%) |
| Current anticholinergic use | 6 (15.4%) |
| Objective findings | |
| Vaginal atrophy | 18 (46.2%) |
| Mean catheterized postvoid residual | 38.6 $cm^3$ (range 5–180 $cm^3$) |
| Mean POP-Q point Ba | −1.7 (range −3 to +4) |
| Positive empty cough stress test | 14 (35.9%) |
| Negative empty, positive full cough stress test ($n$=23) | 6 (26.1%) |
| Urodynamic findings | |
| Detrusor overactivity | 14 (35.9%) |
| Urodynamic stress incontinence | 32 (82.1%) |
| Mean maximum urethral closure pressure | 48.3 cm H2O (range 8–111) |
| Abdominal leak point pressure ≤60 cm H2O | 2 (5.1%) |
| Subjective findings | |
| Symptoms of stress incontinence | 35 (89.7%) |
| Symptoms of urge incontinence | 31 (79.5%) |
| Among those with mixed symptoms ($n$=27) | |
| Stress predominant symptoms | 11 (40.7%) |
| Urge predominant symptoms | 14 (51.9%) |
| Neither symptom predominates | 2 (7.4%) |
| Nocturia (greater than two episodes per night) | 15 (38.5%) |
| Urinary urgency | 33 (84.6%) |
| Pad use | 21 (53.8%) |
| Hesitancy | 3 (7.7%) |
| Feeling of incomplete bladder emptying | 10 (25.6%) |

12.8% had undergone a prior anti-incontinence procedure and 15.4% were currently on an anticholinergic medication. In the history of present illness, 89.7% mentioned some degree of stress incontinence and 79.5% described urge incontinence. Of those with complaints of mixed incontinence, 40.7% were stress predominant and 51.9% were urge predominant. Review of the urodynamics (RMW) was performed in order to categorize cases with detrusor overactivity, 35.9%, or with urodynamic stress incontinence, 82.1%, according to International Continence Society definitions [1].

Each case was read by four reviewers, thus totaling 156 cases evaluated, both with and without urodynamics. The number of cases diagnosed with stress, urge, or mixed incontinence increased following urodynamic evaluation (Table 4).

To evaluate the impact of urodynamics on the diagnosis, the probability of a diagnostic change was determined. After the addition of urodynamics, the diagnosis of stress incontinence (present, absent, or indeterminate) was estimated to change 35.9%; urge incontinence (present, absent, or indeterminate) was estimated to change 41.2% and mixed incontinence was estimated to change 35.7%. Reader-to-reader differences accounted for <1%, 16.2%, and 2% of the total variance, respectively (Table 5).

Following urodynamic testing, the probability that medical treatment would be changed was 26.9%, 45.5% for surgical treatment and 46.1% for conservative treatment. Reader-to-reader differences accounted for 3%, <1%, and 8.5% of the total variance in each analysis, respectively

**Table 4** Diagnostic and treatment changes following urodynamics, empiric data

| | Based on H&P alone, $n$ (%), $n$=156 | After urodynamic evaluation, $n$ (%), $n$=156 |
|---|---|---|
| Diagnosis | | |
| Stress urinary incontinence | 82 (52.5) | 106 (74.4) |
| Urge urinary incontinence | 75 (48.1) | 124 (79.5) |
| Mixed incontinence | 39 (25.0) | 87 (55.8) |
| Incomplete bladder emptying | 15 (9.6) | 14 (9.0) |
| Chronic retention of urine | 0 | 6 (3.8) |
| Functional incontinence | 1 (0.6) | 2 (1.3) |
| Intrinsic sphincter deficiency | – | 33 (21.1) |
| Detrusor overactivity | – | 59 (37.8) |
| Medical treatments | | |
| Imipramine | 12 (7.7) | 7 (4.5) |
| Alpha-agonist | 3 (1.9) | 3 (1.9) |
| Anticholinergic | 100 (64.1) | 99 (63.5) |
| Duloxetine | 1 (0.6) | 0 |
| Topical estrogen | 5 (3.2) | 6 (3.8) |
| Bethanechol | 1 (0.6) | 5 (3.2) |
| None | 34 (21.8) | 36 (23.1) |
| Surgical treatments | | |
| Retropubic midurethral sling | 32 (20.5) | 51 (32.7) |
| Transobturator midurethral sling | 29 (18.6) | 35 (22. 4) |
| Burch retropubic urethropexy | 0 | 0 |
| Traditional suburethral sling | 4 (2.6) | 3 (1.9) |
| Urethral bulking agent | 8 (5.1) | 4 (2.6) |
| Sacral neuromodulation/tibial nerve stimulation | 21 (13.5) | 29 (18.6) |
| None | 62 (39.7) | 34 (21.8) |
| Conservative treatments | | |
| Decreased oral intake | 43 (27.6) | 11 (7.1) |
| Physical therapy | 74 (47.4) | 99 (63.5) |
| Incontinence ring/dish | 15 (9.6) | 12 (7.7) |
| Timed voids | 13 (8.3) | 16 (10.3) |
| Intermittent self-catheterization | 4 (2.6) | 8 (5.1) |
| Bedside commode | 1 (0.6) | 0 |
| Expectant management | 0 | 3 (1.9) |
| None | 6 (3.8) | 6 (3.8) |

**Table 5** Random effects model for incontinence diagnoses and treatment recommendations

| | Proportion of cases when diagnosis changed, % (95% CI) | Reader-to-reader variability (rho), % | Reader-specific changes (%) |
|---|---|---|---|
| Diagnosis | | | |
| Stress urinary incontinence | 35.9 (28.8, 43.7) | <1 | 4.2, 35.9, 30.8, 30.8 |
| Urge urinary incontinence | 41.2 (23.0, 62.2) | 16.2 | 23.1, 66.7, 23.1, 56.4 |
| Mixed incontinence | 35.7 (26.9, 45.6) | 2.0 | 25.6, 51.3, 5.9, 30.8 |
| Incomplete bladder emptying | 23.2 (8.8, 48.7) | 26.1 | 28.2, 61.5, 12.8, 7.7 |
| Chronic retention of urine | 13.4 (8.9, 19.8) | <1 | 17.9, 17.9, 7.7, 10.2 |
| Functional incontinence | 8.8 (3.1, 22.2) | 17.7 | 7.7, 20.5, 0, 15.4 |
| Treatments | | | |
| Medical | 26.9 (18.6,37.2) | 3 | 33.3, 12.8, 26.3, 36.8 |
| Surgical | 45.5 (37.8,53.4) | <1 | 46.2, 35.9, 48.7, 51.3 |
| Conservative | 46.1 (31.1, 62.0) | 8.5 | 61.5, 23.1, 57.9, 43.6 |

(Table 5). Empiric data regarding treatment changes are presented in Table 4.

The impact of urodynamic parameters and diagnoses on treatment plans was assessed. Treatment recommendations were more likely to change following complex urodynamic analysis if there was a negative cough stress test during the initial evaluation, 61.8% (95% CI, 49.7 to 72.5%) compared to those with a positive cough stress test at the initial evaluation, 31.3% (95% CI, 22.1% to 42.2%), $p<0.0001$. Of cases with a negative cough stress test at the initial evaluation, the probability that treatment would be changed in the absence of urodynamic stress incontinence was estimated at 38.9% (95% CI, 24.6% to 55.4%) and 87.5% (95% CI, 71.2 to 95.2%) when urodynamic stress incontinence was present, $p<0.001$. Reader-to-reader differences account for <1% of this variance. The impact of urodynamic diagnoses was also evaluated. Medical treatments changed 1.89-fold more often when detrusor overactivity was absent (compared to present or indeterminate); detrusor overactivity did not significantly change surgical treatments. When the diagnosis of intrinsic sphincter deficiency was present, there was a trend towards changing medical and surgical treatment recommendations more often (compared to when it was absent, Table 6). The following urodynamic parameters did not impact the estimated probability of changing the treatment recommendations: maximum urethral closure pressure, abdominal leak point pressure, flow rate, interrupted voiding pattern, and post-void residual values.

Patients complaining of stress incontinence are sometimes categorized as being straightforward or complex. Straightforward stress incontinent patients are typically those ≤65 years with urethral hypermobility, a positive cough stress test, normal postvoid residual, no prior anti-incontinence surgery, no neurologic disease, and no prolapse beyond the hymen[4]. In this study, 35 cases involved complaints of stress incontinence: ten met criteria for being straightforward and 25 were complex. Among straightforward patients, the probability of a change in surgical treatment following urodynamics was estimated at 22.4% (95% CI, 9.9% to 45.7%) compared to 54.0% (95% CI, 44.2%, 63.5%) among complex cases ($p=0.003$); 10.1% and <1% of this variance was due to reader-to-reader differences, respectively. Eight of the complex cases had a positive cough stress test before urodynamics and the probability of changing the surgical treatment for this group

**Table 6** Random effects model adjusted for the diagnosis of detrusor overactivity or intrinsic sphincter deficiency

| Adjustment factor | Changed medical treatment, % (95% CI) | Changed surgical treatment, % (95% CI) |
|---|---|---|
| Unadjusted | 26.9 (18.6, 37.2) | 45.5 (37.8, 53.4) |
| Detrusor overactivity | | |
| Absent ($n=67$) | 36.1 (21.8, 53.4) | 44.8 (33.4,56.8) |
| Present ($n=59$) | 19.1 (9.6, 34.5) | 40.0 (27.5,51.9) |
| Indeterminate ($n=30$) | 20.7 (8.1, 43.6) | 60.0 (41.9, 75.7) |
| Reader-to-reader variability (rho) | 6 | <1 |
| Intrinsic sphincter deficiency | | |
| Absent ($n=98$) | 24.4 (16.3, 34.8) | 41.8 (32.5, 51.8) |
| Present ($n=33$) | 37.7 (21.4, 57.3) | 56.2 (39.0, 72.1) |
| Indeterminate ($n=25$) | 24.5 (11.1, 45.7) | 46.2 (28.4, 65.0) |
| Reader-to-reader variability (rho) | 1.1 | <1 |

was estimated at 33.9% (95% CI, 18.1 to 54.3) with reader-to-reader differences contributing 4.1% of the variance.

To evaluate whether changes in treatment recommendations were reflected by the physicians' assessment of the usefulness of the urodynamics, the readers were asked a series of questions followed by VAS (Table 2). In cases without a urodynamic evaluation, when asked "Do you feel that the addition of urodynamics would be helpful in forming a treatment plan for this patient?", more affirmative responses were associated with the cases in which the medical (8.1 cm versus 7.3 cm, $p=0.04$) or surgical treatments changed (7.8 cm versus 7.2 cm, $p=0.08$ on a 10-cm VAS). In cases with urodynamics, these differences were more robust. When readers were asked if the addition of urodynamics helped them make a treatment plan, more affirmative responses were associated with cases in which there was a change in the treatment recommendation: mean scores of 8.1 cm versus 6.6 cm when surgical recommendations changed ($p=0.0005$) and 8.3 cm versus 6.9 cm when the medical recommendations changed ($p=0.008$). Similarly, readers responded more affirmatively when asked if the addition of urodynamics improved the treatment recommendations: 8.2 cm versus 6.3 cm ($p<0.00001$) when surgical treatments changed and 8.2 cm versus 6.8 cm ($p=0.01$) when medical treatments changed.

A subset of the clinical cases was reread by the reviewers to determine intrareader reliability. Kappa values greater than 0.6 represent substantial agreement and values around 0.4 represent moderate agreement. The overall kappa for intrareader reliability for the medical treatment recommendations without urodynamics was 0.43 (individual kappas 0.25, 0.4, 0.32, 0.57) and with urodynamics was 0.22 (individual kappas 0.11, 0.21, 0.26, 0.18). The overall kappa for intrareader reliability for the surgical recommendations without urodynamics was 0.6 (individual kappas 0.36, 0.82, 0.19 and 0.85) and with urodynamics was 0.58 (individual kappas 0.58, 1.0, 0.27, 0.39).

## Discussion

In this study, the addition of a multichannel urodynamic evaluation changed the planned surgical treatment in 46% of cases and medical treatment in 27% of cases. This suggests a role for urodynamics in developing treatment recommendations for women with urinary incontinence.

Similar to other reports in the literature, this study found that there were diagnostic changes following urodynamic testing [3, 6, 9, 12, 15]. This supports the view that a complete picture of voiding function cannot be obtained by the history and physical alone. Indeed, subjective complaints are often quite different than the objective findings found on a urodynamic evaluation.

While many advocate that urodynamic testing is appropriate for complex patients, such as those with significant pelvic organ prolapse, neurologic disease, or those who have failed prior anti-incontinence procedures [4], there is no such consensus regarding the usefulness of routine preoperative urodynamics, especially for seemingly straightforward patients [11, 14, 15]. This study shows that even among straightforward patients with documented stress incontinence, urodynamics change the treatment recommendations in 22% of cases. It should be noted that there was a high rate of detrusor overactivity in this study, 35.9%, and our findings may not be reproducible in a population with less detrusor overactivity. Other studies have found the impact, and specifically the cost effectiveness, of complex urodynamics to be greater when rates of detrusor overactivity are ≥20% [13].

When urodynamics changed treatment recommendations, this was reflected in the VAS designed to quantify the perceived usefulness of the urodynamics for each physician reviewer. While it is hard to characterize a clinically meaningful improvement on the VAS, there is no question that the proportion of treatment plans modified by urodynamics is clinically significant for this population. The VAS results suggest that the physician readers were aware that their treatment recommendations were being modified by the urodynamic evaluation. This strengthens the argument that the urodynamics played a key role in formulating the treatment plan.

The use of recent, well-documented patient cases, abstracted and deidentified, strengthens this study because it allows for the cases to be evaluated using objective parameters. The complexity of a real patient is hard to artificially replicate or mimic and their use improves the generalizability of these results to the clinical setting.

Weaknesses of this study include the fact that urogynecologists working in the same office may have more similar practice styles than urogynecologists from a more diverse array of geographic and practice settings, thus limiting the generalizability of the reader performances. Moreover, not all urodynamic parameters and diagnoses are standardized, nor are there standards regarding how testing should be performed, which also decrease the generalizability of our results. Another potential weakness is the risk of recall bias and learning effects which exist in any reader study. We made all efforts to minimize this risk including randomizing the order of the cases, having a "washout" period between reviews, deidentification, and relabeling all cases. Finally, with only four readers and 40 cases, this is only a modest reader study.

Some treatment recommendations were chosen infrequently, or in the case of the Burch retropubic urethropexy, not at all. While the physician readers in this study do perform retropubic urethropexies, it was not their first choice for an anti-incontinence procedure in the cases reviewed for this study.

A subset of the cases were reread to evaluate intrareader reliability. Two readers were highly reliable when making treatment recommendations. For the impact of intrarater reliability to truly be evaluated, this study needs to be conducted on a larger scale and in a more diverse setting.

We expected certain urodynamic parameters to be associated with changes in the treatment recommendations. This held true for the diagnosis of detrusor overactivity, which was associated with fewer changes in medical treatment as compared to cases without detrusor overactivity. The impact of other urodynamic parameters and urodynamic diagnoses on treatment changes could not be assessed in this study due to the complexity of the cases and wide array of abnormalities in voiding function. A much larger sample size or fictitious cases with precisely defined urodynamic parameters would be needed to address this question.

This study suggests that urodynamic evaluations unveil subtleties in voiding function which may change treatment recommendations. These subtleties are found following the evaluation of seemingly straightforward patients, as well as those known to be complex. While the urodynamic evaluation provides an opportunity to confirm or exclude detrusor overactivity and to repeat the cough stress test, these findings alone did not account for all treatment changes. Future studies are needed to determine whether these changes in treatment result in improvements in clinical outcomes.

**Conflicts of interest** None.

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