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GERIATRIC BLADDER DYSFUNCTION (G GHONIEM, SECTION EDITOR)

Role of Urodynamics in the Evaluation of Elderly Voiding Dysfunction

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Abstract Voiding dysfunction is a common condition in the elderly that can affect both men and women. Due to the age-associated changes in the lower urinary tract, voiding dysfunction in the elderly is usually complex and multifactorial, necessitating more objective testing sometimes. In this chapter, we will focus on the role of urodynamics in the setting of voiding dysfunction in the elderly. The term voiding dysfunction will be used to refer both to storage and obstructive lower urinary tract symptoms.

Keywords Urodynamics · Geriatric · Elderly · Voiding dysfunction

Abbreviations

AD	Alzheimer dementia
AUA	American urological association
BOO	Bladder outlet obstruction
CVA	Cerebrovascular accident
DHIC	Detrusor hyperactivity with impaired contractility
DO	Detrusor overactivity
DU	Detrusor undercontractility
ICS	International continence society
IPSS	International prostate symptom score
ISD	Intrinsic sphincter deficiency
LUTS	Lower urinary tract symptoms
MS	Multiple sclerosis
MSA	Multiple system atrophy
MUI	Mixed urinary incontinence
NPH	Normal pressure hydrocephalus
PFME	Pelvic floor muscle exercise
PCa	Prostrate cancer
PD	Parkinson disease
PMC	Pontine micturition center
PFS	Pressure flow studies
PVR	Postvoid residual
RP	Radical prostatectomy
SUI	Stress urinary incontinence
TBI	Traumatic brain injury
UTIs	Urinary tract infections
UUI	Urgency urinary incontinence
UI	Urine incontinence
VLPP	Valsalva leak point pressure
VUR	Vesicoureteral reflux
VUDS	Videourodynamics

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Introduction

The elderly is defined by the World Health Organization (WHO) as the chronological age of 65 years. With the advances in medical care, the elderly is expected to be a growing sector of our patients' population. The number of individuals aging 65 years or more has increased by 140 million between 1975 and 1995, accounting for 6 and 7 % of the world's populations, respectively. This age group is projected to comprise 10 % of the world population by 2025 [1] and 20 % of the American population in 2030 [2]. Furthermore, those over the age of 85 years are the fastest growing segment of the elderly population in the USA, and the number of individuals 80 years and older will rise from 9.3 million in 2000 to 19.5 million in 2030 [3].

With this increase in the elderly population, we, the urologists, expect a parallel increase in the geriatric patients'

volumes in our practice. In 2006, the elderly patients represented 48 % of the urology outpatient visits. This is the highest rate between surgical subspecialties, exceeded only by ophthalmology and only with a narrow margin [4].

There is no specific standard definition of voiding dysfunction but the condition can be broadly classified to obstructive lower urinary tract symptoms (LUTS), storage LUTS, and urine incontinence (UI). LUTS in the elderly are usually multifactorial. In men, aging is usually associated with benign prostatic hyperplasia (BPH), a condition that per se can cause LUTS. In women, aging is usually associated with some degree of pelvic organ prolapse (POP) and vaginal atrophic changes, two conditions that can also predispose to LUTS. In both men and women, the bladder collagen/elastin ratio changes, again leading to bladder functional changes and hence LUTS. Furthermore, the elderly with LUTS may also encounter one or more of other age-related disease conditions that affect the lower urinary tract function. These disease conditions may include mental, cognitive, and/or physical impairments that may predispose to different forms of voiding dysfunction.

These factors together turn the evaluation of LUTS in the elderly a multifactorial and complicated process. In this setting, urodynamics may provide an invaluable objective tool to further characterize and guide the management of LUTS in the elderly. The value of urodynamics, however, should be weighted against the invasiveness of the procedure and the need for urethral catheterization with possible subsequent infection, pain, or urethral trauma. In this chapter, we will discuss the role of urodynamics in the geriatric voiding dysfunction with specific focus on certain disease conditions that can affect the lower urinary tract in the elderly.

Obstructive LUTS

Obstructive LUTS occur during the voiding phase of the micturition cycle. Some of the obstructive LUTS are perceived by patients at the beginning of micturition (urinary hesitancy), during micturition (weak stream, intermittent stream), or at the end of micturition (postvoid dribbling and sense of incomplete bladder emptying). This may progress to acute or chronic urine retention. Obstructive LUTS are common in the elderly and can be related to bladder and/or bladder outlet. Bladder-related obstructive LUTS include detrusor undercontractility (DU) and acontractile detrusor (AD). Bladder outlet-related obstructive LUTS on the other hand refer to bladder outlet obstruction (BOO). Differentiation of the two entities, during urodynamic studies, can significantly affect treatment decision making and outcome. The addition of imaging studies during video-urodynamics may provide some useful anatomic data. The use of fluoroscopy during the study can diagnose concomitant vesicoureteral reflux (VUR) and/or bladder diverticulum secondary to BOO. Video-urodynamics can also help identify the level of BOO especially in women [5].

When bladder function is weak, different terms have been use. These include the following: impaired bladder contractility (IC), detrusor under contaractility (DU), and more recently detrusor underactivity (DU). Detrusor under contractility (DU) is defined by the International Continence Society (ICS) as "detrusor contraction of reduced strength and/or duration, resulting in prolonged bladder emptying and/or a failure to achieve complete bladder emptying within a normal time span"[6]. There are no standardized cutoff urodynamic values that define DU. Chung et al. used a maximum flow rate of ≤15 ml/s and detrusor pressure of Qmax of <20 cm H2O to define DU in their study of male patients who had radical prostatectomy [7•]. DU should be differentiated from "AD" which is defined by the ICS as "one that cannot be demonstrated to contract during urodynamic studies."

Both DU and AD are common urodynamic findings in the geriatric population. In a study of 449 women, Valentini et al. found predominance of impaired detrusor contractility and high PVR in patients 75–93 years old compared to younger age groups [8]. The elderly are more predisposed to fecal impaction, impaired mobility, and use of multiple medications that can affect the detrusor function [9]. Furthermore, detrusor function was shown to decline with age. This is probably related to the normal detrusor muscle changes with aging with decreased smooth muscle concentration and increased collagen deposition. DU tends to be more in men than women. In a study of urodynamic testing in 1179 patients 65 years of age or older, Jeong et al. reported DU in 40.2 % in men and 13.3 % in women. The rates of DU in this study were found to increase with age in both genders [10].

Detrusor Hyperactivity with Impaired Contractility or Detrusor Overactivity with Detrusor Undercontractility

More commonly observed in the elderly, detrusor hyperactivity with impaired contractility (DHIC) is the urodynamic finding of detrusor overactivity (DO) during the filling and DU during the emptying phases of urodynamic study (Fig. 1). This is usually accompanied with high PVR. Clinically, the patients usually have mixed storage and obstructive LUTS. Elderly patients with urge incontinence were found to have increased detrusor contraction than those with DHIC [11]. We suggest to replace the old term (DHIC) with this newer term (detrusor overactivity with detrusor undercontractility (DODU)) to facilitate understanding and avoid confusion.

In addition to the diagnostic value of urodynamics in differentiation between BOO and DU, urodynamics may provide additional data that can affect treatment plan and help with appropriate patient counseling before surgery. Lewis et al. retrospectively reviewed the charts of 87 of men with urine retention presumed to be secondary to BPH. The

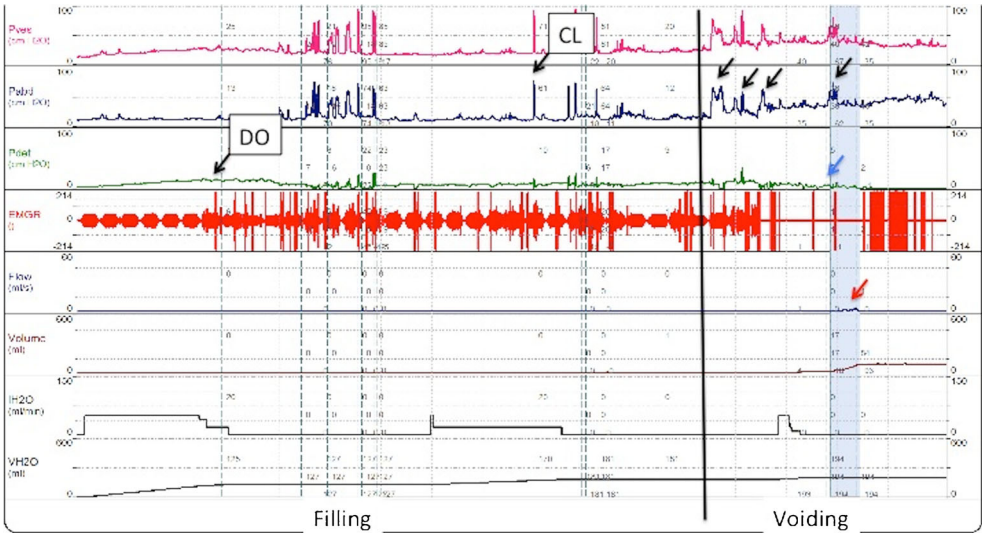

Fig. 1 Detrusor hyperactivity with impaired contractility. Urodynamic tracing of filling cystometry and pressure flow studies in an 86-year-old female with insensible urinary incontinence accompanied with urinary frequency, urgency, increased daytime voiding frequency, and nocturia. Patient also reported sense of incomplete bladder emptying and weak stream. Initial PVR volume assessment in the office was 16 ml. Because of her complex LUTS, she had urodynamic study performed. During filling cystometry, she developed detrusor overactivity (*DO*) with urine leakage at a filling volume of 90 ml. She also leaked with cough (*CL*) with cough leak point pressure of 60 cm H2O at 150 ml. During voiding, she urinated 75 ml with maximum flow rate of 4 ml/s (*red arrow*) and a Pdet at Qmax of 3.3 cm H20 (*blue arrow*). She also showed some valsalva efforts during voiding (*black arrows*)

purpose of the study was to identify renal and bladder abnormalities in those patients. Urodynamic findings were reviewed for the study cohort. Forty-eight percent did not show detrusor activity and 52 % had some detrusor contraction; 23 % did not have BOO and 56 % had decreased bladder compliance [12].

Overactive Bladder

Overactive bladder is defined as the symptom complex of urinary urgency, with or without urgency urinary incontinence (UUI), usually accompanied with frequency and nocturia, in the absence of urinary tract infection or other obvious pathology [13•]. Overactive bladder (OAB) affects 16.9 million American women and another 16.9 million American men. The prevalence of OAB increases with age adding it to the list of disease conditions specific to the elderly. The prevalence of OAB is 4.8 % in women under 25 years and 30.9 % in women over the age of 65 years [14]. In a population-based survey in North America and Europe, the prevalence of OAB was found to be 19.1 % in men and 18.3 % in women at 60 years of age. This was higher than the prevalence of 7.1 % in men and 9.7 % in women at the age of 39 years [15].

The initial treatment for OAB is usually conservative with behavioral changes, fluid management, and bladder retraining (first line) with or without the use of antimuscarinics or β3 agonists (second line) (AUA/SUFU guidelines 2014). In this initial stage of management, urine analysis and assessment of PVR may be sufficient. When more invasive or irreversible treatment is considered, however, urodynamics may become necessary [16•]. Urodynamics in the setting of OAB can provide details about bladder compliance, DO, and BOO. The later can be a cause of OAB symptoms in elderly men with BPH, in elderly women with POP, or in both after previous bladder outlet procedures. When OAB is believed to be secondary to BOO, treatment is focused on treating BOO and does not necessarily follow the regular lines of treatment for idiopathic OAB.

Urine Incontinence

UI (defined as involuntary loss of urine) affects 15–50 % of the elderly. Up to 40 % of patients in the nursing homes have some degree of UI [17]. The types of UI encountered in the elderly are the UUI, mixed urinary incontinence (MUI), and stress urinary incontinence (SUI). The role of urodynamics in UUI was discussed under OAB.

Data regarding the use of urodynamics in SUI is controversial and several conflicting reports have been published. The focus has been on the role of urodynamics in prediction of success after incontinence surgery and predication of voiding dysfunction after incontinence surgery and to resolve the issue of whether or not to perform an antiincontinence procedure at the time of prolapse surgery. Treating occult stress urinary incontinence in pelvic organ prolapse (POP) is a point of argument between surgeons. POP reduction test can reveal occult SUI in some patients. To diagnose occult SUI, the prolapse may be reduced with vaginal packing, rectal swabs,

a speculum blade, or pessary. Ghoniem et al. [18] used a vaginal pack (formed from two rolled 4×4-in. gauze pads) to reduce large cystoceles and found occult SUI in 69 % of the women. They found that the vaginal pack provided superior visualization of the vesicourethral angle during fluoroscopic urodynamics.

In one of the landmark trials, Lemack et al. reported that the valsalva leak point pressure (VLPP) did not correlate with incontinence severity [19]. This finding is supported by data from the Mid-Urethral Slings (TOMUS) trial which showed that VLPP did not affect the surgery outcome [20]. Another recently published important trail is the Value of Urodynamic Evaluation (ValUE) trial. In this study, women who considered for antiincontinence surgery were randomized to either office evaluation only or urodynamics for assessment of SUI before surgery. The primary outcome was treatment success and the secondary outcome was the cost and utility of urodynamics. At 12 months of follow-up, there was no significant difference in the treatment outcome between the two groups. The study concluded that in women with non-complicated SUI, urodynamics did not improve treatment success and was unnecessary replacement of office evaluation [21••]. It should be noted that ValUE trial results apply only to women with no voiding dysfunction and only symptoms of SUI. These are seldom the case in elderly women with more prevalent voiding dysfunction associated with SUI. Also, the trial has a small number of women with intrinsic sphincteric dysfunction (ISD), a condition with more prevalence in elderly women.

There is a large volume of the literature about the use of urodynamics as a predictor of voiding dysfunction after incontinence surgery. In a study by Miller et al., 98 women were investigated for the urodynamic predictors of urine retention following pubovaginal sling. Final analysis included 73 women. Patients who did not show evidence of detrusor contraction during voiding had 19 % urine retention rate after pubovaginal sling compared to 0 % retention rate in patients who voided with detrusor contraction (P=0.007). The study concluded that absent or weak detrusor contraction is a risk factor for urine retention after pubovaginal sling [22••].

Lemack et al. analyzed the data of 579 patients from the Stress Incontinence Surgical Treatment Efficacy (SISTEr) trial and found urodynamics did not predict the development of voiding dysfunction after pubovaginal sling or Burch colposuspension [23]. In a study by Wang et al., abnormal pressure flow studies (PFS) (defined as Qmax<12 ml/s and Pdet Qmax≥20 cm H2O) were associated with worse quality of life and pad test results compared with patients who had normal PFS [24].

It can be perceived from the abovementioned and other published data that the role of urodynamics in SUI is a matter of large debate. In general and according to recent American urological association (AUA) guidelines, there is a level C evidence that urodynamics may be performed on patients with signs and symptoms of SUI and in whom an invasive or irreversible treatment is pursued [16•]. The role of urodynamics in the evaluation of occult SUI is discussed below.

Pelvic Organ Prolapse

POP can be managed conservatively or surgically. For patients who are planned for surgical intervention, preoperative evaluation of the lower urinary tract function may be indicated. This is to assure good surgical planning and patient counseling. Concerns related to POP surgery include the development of postoperative de novo UI or voiding dysfunction especially in patients with high-grade (III or IV) prolapse.

Patients with grade III or IV prolapse may have occult SUI that can be unmasked after prolapse surgery. Occult SUI in the setting of POP is possibly related to the urethral kinking, which increases the urethral pressure. It can also be explained by the assoiciated dissipation of stress forces away from bladder neck thus masking SUI [18]. Another possible mechanism of occult SUI is the pop-off mechanism. During the increase in intra-abdominal pressure with cough or valsalva, the prolapsed vaginal wall may absorb the increased intra-abdominal pressure. When POP is successfully reduced after surgery, occult SUI may be unmasked leading to unfavorable outcome. Preoperative urodynamics with prolapse reduction may therefore be helpful in cases with high-grade prolapse and without the symptom of SUI.

Several methods of prolapse reduction during urodynamics have been described. All were found to increase the SUI detection rates. In a secondary analysis of the Colpopexy and Urinary Reduction Efforts (CARE) trial, Visco et al. reviewed the data of 322 women who were stress continent and had stages II–IV prolapse. Patients undergone preoperative urodynamic testing with prolapse reduction using five different methods (speculum, swab, forceps, manual, and pessary). The study showed that only 3.7 % of women demonstrated SUI without prolapse reduction while 19 % of women demonstrated SUI with prolapse reduction during urodynamics. Speculum prolapse reduction was associated with the highest (30 %) and pessary with the lowest (6 %) SUI detection rates. The study also showed that preoperative SUI with prolapse reduction during urodynamics was associated with high risk for SUI at 3 months after surgery [25].

The role of urodynamics in predicting voiding dysfunction after prolapse surgery has also been looked at. In a retrospective study of 87 women with POP who underwent surgery, urodynamics with prolapse reduction was performed preoperatively and the study findings were correlated with postoperative uroflowmetry, PVR, and symptoms scores. The study showed the cough stress test to be sufficient for the diagnosis of occult SUI, the presence of DO was a good predictor of

persistent postoperative urgency and UUI. Furthermore, the study showed that poor detrusor contractility during preoperative urodynamics predicts large postoperative PVR [26].

Benign Prostatic Hyperplasia

BPH is a disease of aging men. The histological prevalence in autopsy studies was shown to be 8, 50, and 80 % in the fourth, sixth, and nineth decades of life, respectively [27]. Men with BPH may have obstructive, storage, or mixed LUTS. The mechanism of how BPH causes voiding symptoms is not fully understood and believed to be beyond the simple concept of mechanical outflow obstruction caused by the enlarged gland. Classic teaching dictates that BOO secondary to BPH is due to combination of prostate enlargement (static component) and increased prostatic smooth muscle tone (dynamic component).

The role of urodynamics in the evaluation of voiding dysfunction in patients with BPH is controversial. Research showed lack of correlation between the presence of BOO and treatment outcome in BPH patients. It was also found that LUTS in BPH patients do not correlate with BOO. Therefore, it is not unusual for a BPH patient to have BOO without bothersome LUTS. Similarly, over one fourth of patients admitted for TURP have no BOO [28]. The Agency for Health Care Policy and Research considers urodynamics as optional in the evaluation of LUTS in men with BPH [29].

According to the AUA guidelines, the use of urodynamics in BPH evaluation is limited to specific situations [30]. Initial evaluation usually starts with a detailed history, physical examination (including rectal examination) and symptom score assessment. For the latter, the International Prostate Symptom Score (IPSS) is the standard utilized questionnaire. Patients who have IPSS of 0–7 are considered to have mild symptoms and need no further evaluation or treatment. Those who have IPSS of 8–19 (moderate) or 20–35 (severe) may need additional testing such as non-invasive uroflowmetry and PVR assessment. Since the uroflow outcome is a combination of detrusor contraction and bladder outflow resistance, abnormal uroflowmetry refers to abnormal detrusor function, increased bladder outlet resistance (BOO), or combination of both. Uroflowmetry cannot differentiate these three entities which can be only differentiated using PFS. Uroflowmetry is a good screening tool for the lower urinary tract function and can also be used post treatment to assess treatment outcome. The generally accepted cutoff value for normal uroflow is 10 ml/s below which uroflow is considered abnormal [31].

Filling cystometry in BPH patients with LUTS can evaluate for cystometric capacity, DO, and the status of bladder compliance. Filling cystometry can demonstrate DO in about 50 % of men with LUTS [32] and 25–40 % in men with BOO [33]. DO may reflect sever degree of BOO [34] and can risk treatment failure if persists after surgical treatment of the prostate and relief of obstruction [32, 35]. DO cannot expect treatment outcome however.

Filling cystometry can also assess bladder compliance which may deteriorate in patients with long-standing BOO. Research showed that about one third of patients who have BOO also develop abnormal bladder compliance [36] with older men and those with sever BOO being more vulnerable for bladder compliance deterioration [37]. Recent studies suggest that low compliance in the setting of BOO is reversible with surgical correction; therefore, those patients are good surgical candidates [38]. When long-term BOO is expected, I prefer to do video-urodynamics as opposed to regular urodynamics. Video-urodynamics provides anatomical details of possibly associated bladder diverticula and/or VUR that may develop in this group of patients (Fig. 2).

As opposed to uroflowmetry, PFS add the advantage of detrusor muscle evaluation at the time of uroflow. PFS are indicated in BPH patients with moderate to severe IPSS score and in whom invasive surgery is considered. PFS are also indicated if Qmax is above 15 ml/s in patients with LUTS, if DU or AD is suspected, in patients with suspected neurogenic bladder and in patients who failed previous prostate surgery [39].

Efforts have been made to evaluate the role of urodynamics in predicting treatment outcome in BPH patients. There was found no correlation between the findings of uroflowmetry or PFS and the outcome of medical therapy of BPH [40, 41]. Urodynamics is not considered therefore as a pretreatment testing in patients considered for medical treatment. In patients who received surgical treatment, patients who had BOO during PFS tend to do better after treatment than those who were unobstructed but significant number of the unobstructed patients also experienced successful outcome [42–44]. Furthermore, a recent study suggests favorable outcome after prostate resection in patients with DU. In this study, the authors retrospectively reviewed the outcome of transurethral resection of the prostate (TURP) in 20 patients with DU and BPH symptoms. Patients' ages ranged between 57 and 88 years (mean 74.2 years). Compared with before TURP, all patients in the study have improved IPSS, quality of life questionnaires, maximum urine flow (Qmax), bladder compliance, maximum cystometric capacity and detrusor pressure at Qmax (Pdet at Qmax). The authors concluded that TURP should not be a contraindication merely based on the urodynamic finding of DU. The study sample is very small however [45].

Voiding Dysfunction and Prostate Cancer Treatment

According to the American cancer society (2008), prostate cancer (PCa) is the most common non-cutaneous cancer in US

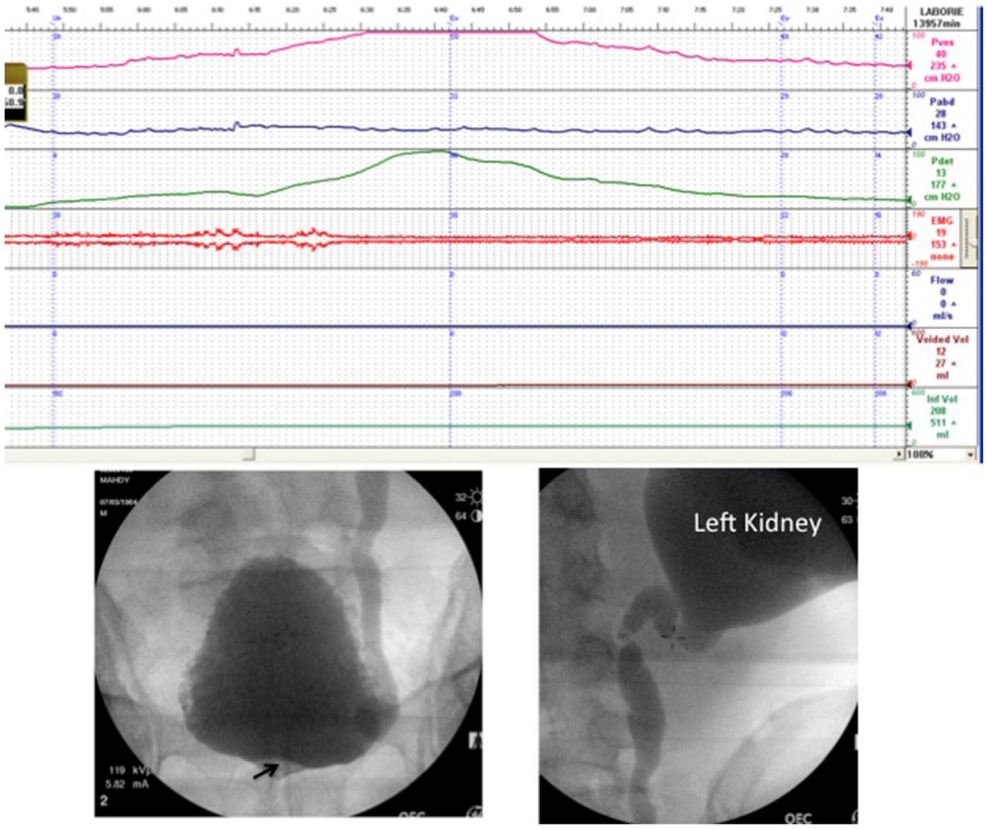

Fig. 2 Video-urodynamics in a 73-year-old male who presented with nocturnal enuresis. Postvoid residual urine volume was 550 ml. The pressure flow study (*top*) shows bladder outlet obstruction (PDet at Qmax 86 cm H2O with no urine flow). Voiding cystourethrogram (*bottom*) shows grade IV left vesicoureteral reflux. Note the filling defect corresponding to the enlarged median lobe of the prostate (*arrow*). The patient obtained TURP, his nocturnal enuresis resolved, residual volumes returned to normal values, and left hdyronephrosis significantly improved

men. The disease is associated with aging and was diagnosed in only 2 % of men below the age of 50 [46•]. About 63 % of PCa patients are diagnosed at ages above 65 with median age of diagnosis being 68 years [47].

Treatment options for localized PCa include watchful waiting, active surveillance, radiation therapy, and radical prostatectomy (RP). Voiding dysfunction after radiation therapy and RP for PCa is well known and usually multifactorial. In the following paragraphs, I will focus on the role of urodynamics in voiding dysfunction after those two treatment modalities for PCa.

Voiding Dysfunction After RP

The most commonly encountered LUTS after RP is UI. The UI rate after RP remains high even with the advances in the surgical technique and technology. UI after RP is primarily SUI related to ISD [48–50] but bladder dysfunction after such a major pelvic surgery was also found to have a role [51–53]. Examples of bladder dysfunction after RP include DO, low bladder compliance, impaired detrusor contractility, or changed bladder sensation. In a study of 264 men who had RP, 108 were found to have DU. About half of DU patients showed some valsalva efforts during urodynamics [7•]. A 9.1 % incidence of DU was also found after laparoscopic RP [54].

Multiple factors contribute to these changes including patient age, preexisting BOO secondary to the enlarged prostate, and bladder denervation after extensive pelvic dissection during RP [49]. These factors together may make it difficult to characterize voiding dysfunction in this setting. Urodynamics therefore could be an ideal tool to characterize and possibly predict the development of LUTS after RP in those patients.

There is not much in the literature regarding the role of urodynamics before RP. A study by Aboseif et al. showed preoperative detrusor dysfunction diagnosed by urodynamics to be a poor prognostic indicator for postoperative UI [55]. This is particularly significant in patients who did not report any LUTS before the RP procedure.

The role of urodynamics in the evaluation and treatment of LUTS after RP has also been investigated. Studies showed that patients, who received incontinence treatment based on urodynamic findings, have achieved 87–88 % "socially acceptable" continence rate [52, 56].

It has to be emphasized that up to 93 % of UI after RP resolves with conservative measures at the end of the first year after surgery [57] and secondary to sphincter recovery and improvement of bladder capacity over time [58, 59]. Therefore, urodynamic assessment should be delayed and reserved to patients who fail conservative measures and in whom invasive surgery is pursued.

Voiding Dysfunction After Prostate Cancer Radiation Therapy

Development of LUTS is a known side effect related to pelvic irradiation. Early after radiation, patients may develop symptoms of frequency, urgency, dysuria, and hematuria. Obstructive symptoms may also develop. Acute onset symptoms after radiation treatment are usually temporary and self-limited; however, LUTS long term after radiation treatment are usually more severe and progressive. In the long term after radiation treatment, patients may develop bladder dysfunction with decreased bladder capacity and compliance, DO, and/or impaired detrusor contraction. ISD and urethral stricture may also develop.

Brachytherapy is more associated with LUTS than external beam radiation with urine retention rate of up to 22 %, and approximately 10 % of patients need TURP. The rate of UI after TURP following brachytherapy is 20–40 % [60]. In a study of 110 patients who received brachytherapy for PCa, patients were assessed for changes in IPSS, urolflowmetry, and prostate volume. Eighty-two patients received brachytherapy alone while 28 received combination brachytherapy and external beam irradiation. At 1 and 6 months after treatment, a significant increase in the mean IPSS was found, which returned to the baseline after 12 months. Similarly, the maximum flow rate, voided volume, and PVR showed transient deterioration at 1 and 6 months and returned to baseline after 1 year following radiation treatment [61].

Video-urodynamics may be useful in the evaluation of LUTS late after PCa radiation therapy. Blaivas et al. [62] reviewed the database of 47 men aged 54–88 years who had persistent LUTS 6 months or more after brachytherapy. Evaluation included history, physical examination, IPSS, 24-h voiding diary, uroflowmetry PVR, cystoscopy, and video-urodynamics. The median time for evaluation was 1.5 (0.5–13)years after brachytherapy. Thirty-seven men (79 %) were found to have OAB symptoms, 31 (71 %) have incontinence, 21 (44 %) have obstructive LUTS, and 12 (26 %) have dysuria. When urodynamic findings for the study population were compared to men with unselected causes of LUTS, DO was seen in 28 of 33 (85 %) men after brachytherapy compared with 252 of 541 (49 %) of unselected ($P<0.001$) and urethral obstruction in 24 of 33 (73 %) men post brachytherapy compared with 374 of 541 (69 %) unselected ($P=0.85$) [62].

The role of urodynamics in prediction of LUTS after radiation treatment has also been investigated. In a retrospective review of 105 patients, uroflowmetry was found to be a significant individual predictor of genitourinary tract morbidity after brachytherapy for PCa [63]. Similarly, Henderson et al. have found urodynamic studies can possibly predict the risk of urine retention and need for self-catheterization after brachytherapy [64].

Voiding Dysfunction After Treatment of Gynecologic Cancer

Some of the gynecologic cancers are associated with aging such as ovarian, vulvar, and endometrial cancers. Treatment may include radical pelvic surgery and/or chemo-radiation; all can affect the lower urinary tract function and can lead to voiding symptoms. Radical hysterectomy can cause voiding dysfunction due to disruption of the autonomic innervation to the bladder and urethra during dissection at the anterior, lateral, and posterior parametrium as well as the vaginal cuff.

In a retrospective study of 22 patients aged 22–47 (mean 31)years and who had radical hysterectomy for cervical cancer, Fishman et al. reported on the pattern of voiding dysfunction after the procedure and the role of urodynamic evaluation in further management. Patients had uroflowmetry, gas cystometry, and PVR measurements before and after radical hysterectomy. A mailed-in symptom questionnaire was also provided. Twenty patients responded to the questionnaires. The authors described the type of voiding dysfunction after radical hysterectomy to be disruption of the bladder and urethral nerve supplies. Urine retention in the study tended to change overtime with trend toward stabilization by the end of the first year. The study population also developed decreased bladder sensation, which was thought by the authors to increase the chance for recurrent urinary tract infections (UTIs). The authors also found an important role for urodynamics in characterization of voiding dysfunction and guiding individualized treatment in this cohort. Although the study provides some input about the voiding dysfunction after radical hysterectomy, it should be noted the retrospective nature of the study, the small sample size, the younger age of patients included in the study, the possible difference in urodynamic technique from the study time, and the fact that significant surgical advances have been made since the study was published [65].

Chen et al. [66] evaluated 95 patients for urodynamic changes after radical hysterectomy for cervical cancer. Eighty-three patients who did not have UTIs were included. Forty-two patients were found to have voiding dysfunction after surgery. The most commonly encountered urodynamic changes were low bladder compliance, detrusor dysfunction, and DO [66].

Comparing the clinical and urodynamic findings between patients who had radical hysterectomy and those who had concurrent chemo-radiation for cervical cancer, Katepratoom et al. evaluated 70 cancer survivors using urodynamics. The chemo-radiation group was treated with 54 Gy pelvic radiation with 2–3 high-dose-rate brachytherapy, concurrent with platinum-based chemotherapy. The radical hysterectomy group received type III radical hysterectomy without radiation treatment. Voiding dysfunction (particularly abdominal straining and high PVR) was more encountered in the

hysterectomy (68 %) compared with the chemo-radiation (60 %) groups. Storage dysfunction (particularly low bladder compliance and increased bladder sensation) was more significant in the chemo-radiation group. There was no difference in incontinence rates between the two groups [67].

Although most of the studies that investigated the impact of radical pelvic surgery and radiation of voiding symptoms in women were performed on cervical cancer patients, the concept of pelvic denervation can be applied to radical pelvic surgery for other gynecologic cancers and which are more seen in the elderly. This may suggest a role of urodynamics for evaluation of LUTS in those patients as well.

Neurogenic Bladder

Neurogenic bladder is bladder dysfunction secondary to neurologic disease. Several neurologic conditions can cause neurogenic bladder. The role of urodynamics in the evaluation of neurogenic bladder is well established in certain neurologic diseases (e.g., spinal cord injury and menengiomyelocele), but not well defined in others. Although the bladder dysfunction can more or less be expected knowing the underlying neurologic condition, overlap usually exists and case-by-case evaluation is therefore necessary. The goals of neurogenic bladder management are to assure sufficient bladder emptying, treat urine incontinence, preserve the upper tract function, and avoid neurogenic bladder-related complications. Urodynamics in the setting of neurogenic bladder may provide invaluable information that further characterize the patient symptoms, guide further management, and hence help achieving those goals [68].

As previously mentioned in this chapter, LUTS in the elderly can be related to other confounding factors in addition to the neurogenic bladder itself. In this situation, urodynamics may provide more objective information that can help characterize the condition. In neurogenic bladder patients with storage LUTS, urodynamics can determine the status of bladder capacity and compliance, detrusor muscle stability, and sphincter function [69–71]. In those with obstructive LUTS, the voiding phase of the study can differentiate between BOO and detrusor dysfunction being the cause for patient symptoms. Furthermore, urodynamics can assess for the coordination between the detrusor muscle and smooth/striated muscle sphincters detecting detrusor sphincter dyssenergia, which can have a negative effect on bladder emptying and renal function [72].

In this chapter, I will focus on the role of urodynamics in neurologic conditions most commonly seen in the elderly.

Cerebrovascular Accident

Cerebrovascular accident (CVA) is a common condition in the elderly with an estimated prevalence of 60/1000 after the age of 65 years and 95/1000 in persons over 75 years of age [73]. The initial urologic presentation in patients with CVA is usually urine retention secondary to AD or DU. Later during the course of the disease, patients usually develop UI. UI (usually with urgency and frequency) in the setting of CVA is mostly related to DO [74]. Stress incontinence secondary to sphincter weakness and incontinence related to cognitive impairment can also be found in those patients. In elderly men with CVA, the common pathology of BPH with subsequent BOO can produce OAB symptoms similar to those related to CVA. It has been found that 50–70 % of BPH patients have DO during urodynamic study [75]. This data, together with the fact that aging per se can affect detrusor function [76], make the evaluation of LUTS in CVA men a challenging task.

In a study of 38 men with CVA, Nitti et al. have found that presenting symptoms did not predict the urodynamic findings of BOO or neurogenic DO [75]. Urodynamics in this patient population can therefore help differentiate these underlying mechanisms of LUTS.

OAB symptoms in CVA patients may be mixed with DU. Natsume ran a retrospective analysis of urodynamic studies to investigate the detrusor contractility status in 57 patients (34 men and 23 women) who suffer CVA. DU was defined in the study as maximum contractile power value of less than 10 W/m^2 in men and 8 W/m^2 in women in the absence of BOO. The author found decreased overall value of detrusor contractile power and large PVR in those patients. This finding was found more prevalent in women than men. Interestingly, 67 % of men and 80 % of women with DU were found to have OAB symptoms. Furthermore, 8 of the 23 men and 8 of the 19 women who had OAB symptoms were found to have DU [77]. The diagnosis of DU in patients with OAB symptoms is of particular importance since some of the known OAB treatments (such as antimuscarinics and botox) may better be avoided in those patients.

Parkinson Disease and Multiple System Atrophy

Parkinson disease (PD) is a neurodegenartive disease that affects the dopaminergic receptors in the substantia nigra along with other brain areas. Storage symptoms in PD are possibly related to dopamine deficiency with loss of the dopamine inhibitory effect on the micturition reflex. This leads to DO and OAB symptoms [78, 79]. Nocturnal polyuria along the course of the disease is an additional suggested mechanism of storage LUTS in PD.

In addition to the predominant storage LUTS, Parkinson's patients may also develop obstructive LUTS. It is imperative that LUTS related to PD be differentiated from LUTS related

to BPH in elderly men. Detection of BOO during urodynamics suggests BPH being the underlying cause of LUTS as opposed to DU.

Multiple system atrophy (MSA), a condition often confused with PD, is a progressive neurodegenartive disease that affects the basal ganglia along with other areas in the CNS in a more expanded fashion than PD. The clinical differentiation between PD and MSA (striatonigral degeneration type) may be challenging to the treating neurologist. The pattern of voiding dysfunction in those patients may help differentiate the two conditions. MSA patients usually suffer earlier onset of troublesome UI and erectile dysfunction during the course of the disease [80].

Video-uridynamics may further differentiate MSA from PD. In patients with MSA, urodynamic studies showed DO, high PVR, open bladder neck (due to disrupted sympathetic innervation), and weak striated sphincter as during electromyogram (EMG). Weak striated sphincter is specific for MSA as opposed to PD and caused by loss of the anterior horn cells in the Onuf's nucleus, which is spared in PD. This differential diagnosis is important in the setting of voiding dysfunction in those patients especially when surgical treatment is considered. An influential paper by Staskin et al. [81] and which was published years before MSA was recognized has concluded that prostate surgery for treatment of BPH-related LUTS is contraindicated in PD patients. The conclusion was based on the study findings of high incontinence rates after prostate resection in PD patients compared to the general population [81]. In retrospect, it seems that some of the patients reported in Staskin's study actually had MSA not PD. In a more recent study by Roth et al., the authors found favorable results in 70 % of 23 patients with PD who received TURP [82].

Dementia

Dementia is the loss of cognitive ability secondary to atrophic brain changes and loss of the gray and white matter of the brain, particularly in the frontal lobes. Studies showed that in patients with cognitive impairment, cerebral dysfunction affects the frontal lobe control on the micturition reflex. This leads to involuntary detrusor contractions [83]. Involuntary detrusor contraction is interpreted in urodynamic studies as DO. It was therefore thought that DO explains UI in dementia patients. Different underlying mechanisms of UI are also expected however in this patient population [83, 84].

Alzheimer dementia (AD) is the most common type of dementia in the elderly accounting for more than 50 % of patients with dementia [85]. Dementia-associated voiding dysfunction is one of the most difficult to characterize and treat given the patients' cognitive impairment.

The role of urodynamic study is not well investigated in this patient population probably because of the associated behavioral, cognitive, and physical disabilities. In attempt to better characterize UI in patient with AD, Lee et al. prospectively enrolled 144 patients (48 men and 96 women) with AD and UI. Patients' cognitive status and LUTS were evaluated using validated questionnaires and voiding diaries. The authors excluded from the study patients who had severe dementia, bedridden patients, those with indwelling catheters, and patients who received antimuscarinic medications prior to the study. Patients' ages ranged from 56 to 97 years. The authors found UUI to be the most common type of UI in their series. DO was encountered in 57.6 % of patients (52.1 % in men and 60.4 % in women). UI and DO were found to positively correlate with severity of dementia and negatively correlate with the activity status. Unfortunately, the study did not address the role of urodynamics in the diagnosis of other types of UI in the study population [86].

Intervertebral Disc Prolapse

Approximately one third of asymptomatic patients at the age of 60 have one or more lumbar herniated disc [87•]. Neurogenic bladder in those cases can occur secondary to direct spinal cord or nerve compression by the herniated disc. Urinary symptoms vary with the location of disc herniation. About 90 % of symptomatic patients are found to have lumbar disc herniation at the lumbar L4-5 or L5-S1 levels [88]. Urinary retention is the most common urinary symptom in cases of lumbar disc prolapse [89]. A mix of other obstructive and storage LUTS can also be seen in those patients and may sometimes precede urinary retention. The role of urodynamics in cases with disc prolapse is not well defined. Cheek et al. [90] found urodynamics to be more useful after disc prolapse surgery and in order to assess the treatment outcome. The authors suggest that urodynamics before surgery may not differentiate AD secondary to nerve damage from that secondary to bladder overdistention and detrusor decompensation [90]. Common urodynamic findings are AD as the cause of urine retention, normal or increased ladder compliance, and synergic striated and smooth muscle sphincters.

Diabetic Neuropathy

Diabetic neuropathy affects both men and women equally with about 50 % prevalence in patients who had diabetes of over 25 years duration [91]. Storage LUTS are the most commonly encountered form in patients with diabetic neuropathy. As the disease progresses, UI becomes predominant. Most common urodynamic findings are decreased bladder sensation, increased cystometric capacity, DU, increased compliance, and synergic sphincters. This picture may change in elderly patients with diabetic neuropathy. This is because of common vascular changes that can affect the brain or the spinal cord above the sacral roots.

In a study of 23 elderly diabetic patients, the main age was 80 years with 19 women and 4 men included in the study. DO was found in 61 % of patients. Detrusor function was normal in 13 % of patients. Of patients who presented with UI, 76 % had DO while all those who presented with urine retention had either DU or AD. The authors concluded that clinical picture alone cannot predict the urodynamic findings in the elderly with diabetic neuropathy and urodynamics is recommended for evaluation of voiding symptoms in those patients in order to be able to provide the appropriate treatment [92]. Similar findings were reported by Kaplan et al. who found DO in 55 % and BOO in 36 % (mainly men) in their study population [93].

There is no data that suggest diabetic cystopathy affects treatment outcome in BPH patients with the urodynamic finding of BOO, neither there enough data to dissuade the surgical treatment of urodynamically diagnosed SUI in women with diabetic neuropathy. Therefore, the diagnosis of these two conditions should not hinder surgical treatment in patients with diabetic neuropathy.

Traumatic Brain Injury

Traumatic brain injury (TBI) is a common problem in the elderly with the increased risk of fall. Early after the trauma, patients may present with urine retention due to AD. Lesions above the pontine micturition center (PMC) are usually associated with storage symptoms with the urodynamic findings of DO. Compliance is usually normal and the sphincters are synergic. Lesions below the PMC may show evidence of detrusor striated sphincter dyssenergia. Few studies investigated the role of urodynamics in patients with TBI. In a study of 57 patients who survived TBI-induced coma, 30 patients had OAB symptoms. DO during urodynamics was found in 28 patients while 18 had DU. Fifteen patients had pseudodyssenergia. VUR was detected in two of the study population. The authors also found correlation between UUI, DO, and poor neurologic functional outcome. Correlation between DU and left hemisphere injuries was also found [94].

Specifics to the Elderly when Performing Urodynamics

Although we follow a standard technique when performing the urodynamic procedure, these extra precautions should be considered when performing urodynamics in the elderly:

- Communication status: About 60 % of the elderly patients have either hearing and/or vision difficulties [95]. This—in addition to the common impaired mental status in the elderly—can interfere with the appropriate communication with old patients during the procedure.
- Medication list: Most elderly patients take multiple medications. In a Darifenacin study, Hill et al. reported 98.1 % of patients 65 years or older, who use at least one medication in addition to Darifenacin [96]. Similarly, the MATRIX study reported more than 83 % of patients aged 85 years or older were taking more than two medications besides Oxybutinin and 48 % were taking more than six medications [97]. Some of those medications may affect the lower urinary tract function and hence the urodynamic test results (Table 1). The patients' prescription as well as the over-the-counter medications should be reviewed well prior to the test.
- Antibiotic prophylaxis: Advanced age is considered by the AUA Best Practice Policy Statement as "high risk." For high-risk patients, antibiotic prophylaxis before urological procedures (including urodynamics) is indicated even in the absence of preprocedure UTI. If there is diagnosed preprocedure UTI, it should be treated before the procedure. The antimicrobial agents of choice are fluorquinolones or timethoprim/sulfamethoxazole. If the patient is allergic to both medications, alternative antibiotics include amoxicillin/calvulanate, first- or second-generation cephalosporin, or aminoglycosides/ampicillin. Quinolones have the possible side effects of tendonitis and tendon rupture. This risk increases in patients above the age of 60. The elderly therefore should be counseled regarding possible symptoms of tendonitis and advised to rest the affected joint and contact their doctor. According to the American Heart Association, antibiotic prophylaxis before genitourinary procedures solely to prevent infective endocarditis is no longer recommended. In patients who had previous orthopedic surgery, antibiotic prophylaxis is not indicated for pins, screws, or plates. Antibiotic prophylaxis is indicated however for patients who have risk for hematogeous total joint infection spread AND risk for bacteremia associated with urologic procedures. The full statement on antibiotic prophylaxis can be found at this link: https://www.auanet.org/education/guidelines/antimicrobial-prophylaxis.cfm

Table 1 Common medications that can affect the lower urinary tract

Common medications
Antimuscarinic
Alpha blockers
Alpha agonists
Antipsychotics
Antidepressants
Antihistamines
Antispasmodics
Tricyclic antidepressants
Medications for Parkinson disease

- Patient positioning: it is estimated that patients over the age of 65 years are 3.5–4.5 times more likely to undergo hip arthroplasties than patients who are 65 year old or younger [98]. The patient joints and ambulation status should be considered during positioning for the procedure.
- Urodynamic catheter insertion: insertion of the urodynamic catheter may be technically difficult in the elderly. In the elderly females, the vaginal atrophic changes may result in sever vaginal stenosis that makes it difficult to visualize the urethral meatus. In elderly men, enlarged prostate may make it difficult to pass the catheter beyond the prostatic urethra. In women, the use of suitable size vaginal speculum with sufficient illumination may help visualization of the urethral meatus and appropriate insertion of the urodynamic catheter. If the vagina is too tight to allow proper visualization, the catheter can be guided by the examiner's index finger in the vagina localizing the urethra. In men with enlarged prostates as detected from previous physical exams, a Coude tip catheter can be utilized.
- Uroflowmetry: a maximum flow rate of 15 ml/s is generally acceptable as normal [99]. There is some gender- and age-related variations however. The lower limit of maximum flow for men over 65 years old is 9 ml/s and that for women at the same age group is 10 ml/s. This is lower than the cutoff values of 21 ml/s for men and 18 ml for women at age group between 14 and 45 years [100].

Conclusions

Voiding dysfunction in the elderly is usually multifactorial and complex. Therefore, urodynamics may provide additional information to those obtained from the patient history and physical exam. This additional information can guide the diagnosis and further treatment. In certain conditions (e.g., neurogenic bladder), urodynamics may detect lower urinary tract conditions that can have deleterious effects on the upper urinary tract. When conservative treatment is pursued and there is no concern of upper urinary tract deterioration, the use of the relatively invasive urodynamics may be unnecessary. Performing urodynamics in the elderly may be challenging because of age-related mental and physical disease conditions usually found in this patient group. This is in addition to the common use of long lists of medications that can affect the lower urinary tract function in the elderly.

Compliance with Ethics Guidelines

Conflict of Interest Ayman Mahdy and Gamal M. Ghoniem declare no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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