

Chapter 5

Conducting the Urodynamic Study

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Introduction

Multichannel urodynamics (UDS) are a group of tests used to measure different dynamic aspects of the lower urinary tract (LUT) during storage (filling) and voiding [1, 2]. The term “urodynamics” was initially employed by Davis [3] in 1954 to describe tests used to evaluate LUT function.

Lower urinary tract symptoms (LUTS) are often overlapping and insufficient to support a diagnosis alone. Bates coined the often-used expression “the bladder is an unreliable witness,” in 1970, and it is a maxim that often proves to be true in clinical practice. For this reason, obtaining objective confirmation of the patient’s subjective symptoms can be an important element in clarifying complex diagnoses, particularly before proceeding to invasive therapies. However, one should remember that UDS tests do not replace other diagnostic tests such as urinalysis, cystoscopy, or imaging, if needed, and it should be an integral part of the work-up to establish the proper diagnosis, categorize the severity of the condition, and help with choosing treatment options [4].

The main objective of multichannel UDS is to attempt to duplicate the storage and voiding functions of the bladder that are experienced by the patient in daily life to help identify the pathophysiology behind the voiding dysfunction symptoms. There are several key questions that should be kept in mind when thinking about UDS testing.

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When to Consider the UDS Test

Although multichannel UDS is a very helpful test, it has an associated cost. It is an invasive test that is not without discomfort and may carry a risk of infection. It is also expensive. It is therefore imperative that one ask several questions: (1) if the UDS study is needed? (2) what is the information being sought by the exam? and (3) if the information obtained assist with diagnosis and management?

There are several guidelines available to help identify the role of UDS in clinical practice. The American Urological Association (AUA) Urodynamics guideline can be reviewed at the AUA website [5] (<http://www.auanet.org/education/guidelines/adult-urodynamics.cfm>). A general outline of the proper indications for UDS in clinical practice would include [6]:

1. Characterization of LUT dysfunction and identification of problems associated with LUT dysfunction.
2. Identification of factors causing or contributing to voiding dysfunction.
3. Identification of risk factors associated with LUT dysfunction that can lead to upper tract deterioration.
4. Assessment of the outcome of the anticipated treatment and possible unfavorable side effects.
5. Evaluation for possible reasons of treatment failure and help to plan for future treatment plans and proper patients counseling.

Based on AUA/SUFU guideline statements, the following indications for performing UDS can be summarized [5, 7]:

1. *Indications to perform UDS in patients with stress urinary incontinence (SUI) include:*
 - a. When considering invasive surgery, a post-void residual urine (PVR) should be assessed.
 - b. Clinician may consider multichannel UDS in patients with both symptoms and clinical findings of SUI before invasive treatments. UDS is considered helpful in patients with complicated history such as previous surgery, mixed storage symptoms, or voiding symptoms.
 - c. In patients with high-grade pelvic organ prolapse (POP), UDS should be performed with POP reduction to assess for occult SUI and other detrusor dysfunction issues.
2. *Indications to perform UDS on patients with overactive bladder (OAB), Urgency Urinary Incontinence (UUI), and Mixed Urinary Incontinence (MUI) include:*
 - a. When it is important to determine the presence or absence of altered bladder compliance, detrusor overactivity (DO), or other UDS abnormality in patients who are considering invasive or irreversible procedures.
 - b. In patients with refractory UUI after bladder outlet procedures, clinicians may perform pressure flow studies to assess for bladder outlet obstruction (BOO).
 - c. In women with storage symptoms refractory to treatment following anti-incontinence surgery to identify BOO.

3. *Indications to perform UDS in patients with neurogenic bladder (NGB):*
 The role of UDS in patients with NGB is to identify patients who are at risk for developing upper tract and renal deterioration associated with storage pressure problems and lower bladder compliance.
4. *Indications to perform UDS in patients with LUTS include:*
 In performing UDS in patients with LUTS, a uroflow, PVR, and a pressure flow study (PFS), or multichannel UDS with or without fluoroscopy can be helpful to diagnose the cause of LUTS.
 - a. When an abnormality of voiding/emptying is suggested.
 - b. To determine whether DO or other abnormalities of bladder filling/urine storage are present in patients with LUTS particularly when invasive procedures are considered.
 - c. When it is important to determine whether urodynamic obstruction is present in men with LUTS especially when invasive or irreversible procedures are being considered.
 - d. In women with LUTS when it is important to determine if obstruction is present.
 - e. Clinicians may perform video-urodynamics in properly selected patients to localize the level of obstruction, particularly for the diagnosis of primary bladder neck obstruction.

Pretest Questions

Before ordering any test, questions need to be answered and the proper test to answer these questions needs to be identified. As with any diagnostic test, answers that are obtained should help confirm the diagnosis and/or help with the treatment plan. UDS is not different than any other diagnostic test that is used in clinical practice and questions need to be formulated before ordering the test (Table 5.1).

Table 5.1 Questions to think about while thinking about UDS test for patients

Urodynamics	Questions to ask
Pretest	Q1. Does the patient need this test? Q2. What questions do I need to answer? Q3. How should the test be designed to answer the pre-study questions? Q4. What provocative maneuvers if any do I need to perform?
During the test	Q1. Is the study designed appropriately to answer the questions? Q2. Is the study performed appropriately? Q3. Are there any artifacts or technical problems? Q4. Am I able to reproduce the patient’s symptoms? Q5. If the patient’s symptoms are not reproduced, are there any provocative tests that may reproduce them?
Post-test	Q1. Was the study technically performed well? Q2. Were there any artifacts that needed to be accounted for during interpretation? Q3. Were the patient’s symptoms reproduced during the study? Q4. Were the pretest question/s answered?

Before ordering UDS, a physician should have pretest questions formulated in mind with regard to the study objectives:

1. Why do I need to perform this test?
2. What information do I need?
3. What UDS test(s) do I need to perform to understand the patient's problems?
4. Will the information acquired during the study help in diagnosing the problem and the decision-making process for treatment?
5. How can I reproduce the patient's problems during the study?

At the conclusion of the study, the physician asks the questions

“Were the patients' symptoms reproduced during the study?”

“Did the results of the study correlate with the patient symptoms?”

It is important to recognize that a UDS study is most meaningful when the patient's symptoms are reproduced during test. This should be addressed with the patient during and after the study.

UDS Planning

Physicians should consider UDS testing when the clinical data obtained is insufficient to determine the factors contributing to LUTS [8, 9]. Obtaining such knowledge will help to decide the appropriate treatment for the patient [1]. For example, performing multichannel UDS in patients with neurogenic bladder can not only evaluate bladder function but can also help assess risk factors that could lead to upper tract deterioration. It also helps in counseling patients regarding possible therapeutic outcomes and identifying possible causes behind treatment failure.

A working diagnosis is necessary prior to the multichannel UDS study and the test should be individualized to answer questions generated for each patient prior to initiation of the study. The study is most helpful when the clinical symptoms being investigated are reproduced during the study. If the examiner is unable to reproduce the symptoms, then it is essential to consider tailoring the study or changing the environment to reproduce the symptoms to facilitate a successful study [10]. The following questions, considered prior to and during the study, can help define this process.

1. What questions do I need to answer?
2. What symptoms do I need to reproduce?
3. How can I reproduce the symptom while performing the study?
4. What provocative tests do I need to perform to reproduce these symptoms?

Pretest Arrangements

Pretest Counseling

UDS testing is considered a minimally invasive procedure; however, the patient may view it differently. Patients often perceive this test as an intrusion into their privacy and they may experience a great deal of anxiety associated with several aspects of the test including the environment of the test, urethral and rectal catheterization, voiding in front of strangers, and the embarrassment associated with being exposed. Proper patient counseling including a face-to-face explanation of the test as well as supplemental handouts can reduce this anxiety. A variety of online sources are available which patients can use as additional informational resources. Studies [11, 12] have demonstrated that most of the patients who undergo multichannel UDS testing would not object to repeat testing if needed and that the test causes only minimal anxiety and discomfort. However this does not preclude the fact that pretest counseling is important to prepare the patient for the test. It is crucial to explain to the patient about the expectation of catheterization during the study. Physician–patient communication should continue during the study to alleviate any anxiety or concern.

UDS Personnel

The successful UDS study depends on a team effort. Properly trained staff is crucial in order to perform a good quality study. The staff should be familiar with the patient's history, study requirements, the technique, and the machine settings. Proper interpretation of the study also requires the ability to reliably identify artifacts that occurred during the study. This requires a good understanding of the technique and an open communication between the nurse or technician who is performing the test and the physician interpreting the study. The physician or nurse/technician performing the study must carefully record observations that were made during the study [13, 14]. Annotating the graph appropriately noting such activity as changes associated with changes in position, and provocative maneuvers (coughing, straining, command to void, etc.) will aid in accurately interpreting the study. This requires paying attention to fine details while performing the test and the clinical experience to initiate such maneuvers appropriately and record them succinctly on the study graph and/or event summary [15].

Preparing for UDS Evaluation

History

History of Lower Urinary Tract Symptoms

Completing an appropriate and relevant history is an important part of the preparation for UDS testing. History (Table 5.2) should start with a detailed inquiry about the patient's symptoms and analysis of these symptoms (Table 5.3). Symptoms can be quantified with the aid of available validated questionnaires. Examples of such questionnaires include the International Prostate Symptom Score (IPSS), King's Health Questionnaire (ICIQ-LUTSqol), Symptoms Severity Index (SSI), and Urogenital Distress Inventory-6 (UDI-6). LUT symptoms are often quantitated by means of a voiding diary and pad test. It should be clarified if the patients' symptoms are related to lower urinary pathology, patient physiology, or being practiced out of habit/convenience (e.g., increased urinary frequency secondary to increased fluid intake, using pads as precautionary measures for fear of incontinence) or secondary to other comorbidities (e.g., congestive heart failure or sleep apnea). Documentation should include the duration of symptoms, severity and impact of the symptoms [15].

For example, if the patient has urinary incontinence, it should be properly characterized. Is it associated with physical activity (SUI), Urgency Urinary Incontinence (UII), or other factors? How severe is the leakage? What situations or maneuvers reproduce leakage? How forceful is the urinary stream? Is there any history of treatment or surgery for leakage? Does the patient wear any pads? How many pads? How saturated are the pads? Does the patient wear pads out of convenience for fear of incontinence? Also if the patient has prolapse, does she use any special maneuvers to be able to void such as digital splinting or positioning in order to be able to void [16].

Table 5.2 Pretest evaluation for patients undergoing UDS

History	<ul style="list-style-type: none"> – History of present illness including using validated questionnaires – Past medical and neurologic history – Drug history – Obstetric history – Past surgical history
Physical examination	<ul style="list-style-type: none"> – Genitourinary examination – Abdominal examination – Rectal examination – Vaginal examination – Pelvic floor examination – Focused neurologic examination
Pretest evaluation	<ul style="list-style-type: none"> – Pad test – Voiding diary – Post-void residual urine (PVR) – Urinalysis, culture, and sensitivity – Cystoscopy or imaging if indicated

Table 5.3 LUTS based on International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for female pelvic floor dysfunction [20]

Urinary incontinence symptoms	Definition
Continence	The voluntary control of bladder and bowel function
Urinary Incontinence (UI)	Complaint of any involuntary loss of urine
Urgency Urinary Incontinence (UII)	Complaint of involuntary loss of urine associated with urgency
Stress Urinary Incontinence (SUI)	Complaint of involuntary loss of urine on effort or physical exertion or on sneezing or coughing
Postural (urinary) Incontinence	Complaint of involuntary loss of urine associated with change of body position such as rising from a seated or lying position
Nocturnal enuresis	Complaint of involuntary urinary loss which occurs during sleep
Mixed Urinary Incontinence	Complaint of involuntary loss of urine associated with urgency and also with effort or physical exertion or on sneezing or coughing
Continuous Urinary Incontinence	Complaint of continuous involuntary loss of urine
Insensible Urinary Incontinence	Complaint of urinary loss where the individual is unaware of how it occurred
Coital Incontinence	Complaint of involuntary loss of urine with coitus
<i>Bladder storage symptoms</i>	<i>Definition</i>
Increased urinary frequency	Complaint of voiding occurs more frequently during waking hours than previously deemed normal [20] Complaint of voiding too frequent while awake. Eight voids per day or voiding ≤ 2 h [13]
Nocturia	Complain of interruption of sleep one or more times because of the need to micturate. Each void is preceded and followed by sleep [20] It is waking up at night to void. Zero to one episodes in adults <65 years of age or up to 2 in older adults is considered normal [13]
Urgency	A sudden and compelling desire to pass urine that is difficult to defer
Overactive Bladder symptoms (OAB, Urgency)	Urinary urgency, usually accompanied by frequency and nocturia with or without urgency urinary incontinence, in the absence of urinary tract infection (UTI) or other obvious pathology
<i>Voiding symptoms</i>	<i>Definition</i>
Hesitancy	Complaint of a delay in initiating micturition
Slow stream	Complaint of a urinary stream perceived as slower compared to previous performance or in comparison with others
Intermittency	Complaint of urine flow that stops and starts on one or more occasions during voiding
Straining to void	Complaint of the need to make an intensive effort (by abdominal straining, Valsalva or suprapubic pressure) to either initiate, maintain, or improve the urinary stream
Spraying (splitting) of urinary stream	Complaint that urine passage is a spray or split rather than a single discrete stream
Feeling of incomplete bladder emptying	Complaint that the bladder does not feel empty after micturition
Need to immediately re-void	Complaint that the bladder does not feel empty after micturition
Position-dependent micturition	Complaint of having to take specific position to be able to micturate spontaneously or to improve bladder emptying
Dysuria	Complaint of burning or other discomfort during micturition, discomfort may be intrinsic to the lower urinary tract or external
Urinary retention	Complaint of the inability to pass urine despite persistent effort
<i>Post-micturition symptoms</i>	<i>Definition</i>
Post-micturition leakage	Complaint of a further involuntary passage of urine following the completion of micturition

Past Medical History

The physician should inquire about any other comorbid conditions that can affect the patient's urinary tract. One should specifically ask about any history of any neurological conditions such as lumbosacral intervertebral disc problems, or back/spine surgery, Cerebro-vascular accidents (CVA), Parkinson's disease, and other cerebral abnormalities. In cases of problems with the spinal cord such as spinal cord injuries or spina bifida, the level of the spinal cord lesion should be determined? Other symptoms that may suggest neurological disorders should be kept in mind such as double vision, numbness, or tingling which could be secondary to multiple sclerosis (MS). A history of diabetes and neuropathy is important to elicit, including the duration of the disease. Previous exposure to radiation therapy especially pelvic radiation should be assessed as this could be associated with radiation cystitis, small bladder capacity, and low compliance. It is also important to inquire about a history of constipation as this could affect the bladder function as well as UDS test performance [17]. Any physical or cognitive impairment should be noted as it may require additional arrangements for patient preparation and management during the UDS study [15].

Drug History

Inquiring about drug history is important as some medications can affect the LUT such as narcotics, antihistaminics, antimuscarinics, and sympathomimetics. Also the physician should decide on whether the patient should continue or discontinue any given medication at the time of the study [15]. Discontinuing such medication provides a baseline assessment whereas continuing medications allows an assessment of the patient as they currently exist on the medication.

Obstetric History

It is important to know about the obstetric history including the number of vaginal deliveries, any trauma during delivery, size of the babies, and difficulty during delivery with use of additional equipment (e.g., forceps) to facilitate delivery.

Past Surgical History

It is imperative to obtain the past surgical history as pelvic surgeries could have some effects on bladder function. A prior history of radical hysterectomy or abdomino-perineal resection (APR) could lead to detrusor dysfunction including poor contractility with or without compliance abnormalities. Also a history of prior surgery for prolapse, or incontinence procedures such as slings might suggest alternative diagnoses such as bladder outlet obstruction for which customization of the study would be beneficial. A history of prostate or urethral diseases and/or surgeries in men should be collected as these might suggest difficulties with catheterization for the UDS study.

Physical Examination

Genitourinary Examination

It is important to obtain a good genitourinary (GU) examination prior to the UDS study. The GU examination should include abdominal examination to evaluate for masses, hernia, and/or a distended bladder. The physician can confirm the presence of stress urinary incontinence during the examination by means of a cough stress test. Any urethral abnormalities should be noted. In male patients, a prostate examination should be performed.

Abdominal Examination

The presence of scars from previous surgery especially pelvic surgery is noted. A lower abdominal examination should assess for any evidence of suprapubic fullness indicating a full bladder or urinary retention. Fecal impaction should be noted as this could affect placement of rectal catheters, and in addition, rectal distention due to constipation can significantly affect bladder function [18].

Rectal Examination

Rectal examination is used to assess for anal sphincter tone and strength. It also helps to assess for abnormalities of sacral innervation (S2–S4) via the bulbocavernosus reflex, anal wink, and sensation around the saddle area.

Vaginal Examination

Vaginal examination is extremely important [19] prior to UDS testing. The introitus should be examined for the presence of vaginal atrophy or urethral abnormalities. The presence of vaginal prolapse should be assessed and the degree should be documented. The presence of prolapse can affect LUT function [15, 16] and also may suggest the need to pursue additional maneuvers during UDS testing. For example, if there is significant pelvic organ prolapse, one may choose to reduce it with a pessary during the study in order to assess for occult SUI or alternatively to examine the potential obstructive effects of the prolapse on voiding. The presence of any scar tissue or a urethral abnormality from previous incontinence surgery such as a swan neck deformity should be documented.

Pelvic Floor Muscle

Pelvic floor muscle resting tone and function should be assessed during physical examination and should be noted if it is normal, overactive, underactive, or non-functioning [13, 20, 21].

Focused Neurologic Examination

Neurologic examination should be a part of the evaluation of patients with voiding dysfunction undergoing UDS assessment. The physician should observe for any gait abnormalities and any lower extremity weakness. Sensation of the saddle area and rectal tone is an important part of the neurological examination. Assessment of the sacral reflexes that should be considered to test for sacral nerve integrity. These reflexes are centrally integrated at S2 to S4. The reflex arc is mediated via afferent and efferent limbs within the pelvic nerves. The reflexes [22] include:

1. The anal wink reflex: this can be elicited by tapping the perianal skin and observing for anal sphincter contraction.
2. The bulbo-cavernosus reflex: this is elicited by digital squeezing of the glans penis (or clitoris), which will result in contraction in the anal sphincter or bulbo-cavernosus muscle [18, 23].

If abnormalities are noted in the neurological examination further evaluation is warranted.

Pretest Evaluation

Post-void Residual Urine

PVR is defined as “the volume of urine left in the bladder at the end of micturition” [13, 20] and is often considered an urodynamic test in isolation. According to the AUA guidelines assessment of PVR should be performed in:

1. Patients with SUI or pelvic organ prolapse who are considering invasive procedures.
2. Patients with neurogenic bladder as a part of their evaluation [5].
3. Patients with LUTS as a part of their evaluation to rule out urinary retention as a cause of their symptoms [5].

There are multiple methods to measure the PVR. These include invasive and non-invasive methods. The invasive approaches can be performed via in-and-out catheterization or endoscopy. Non-invasive means include transabdominal ultrasonography using real-time ultrasound or automated systems. It can also be assessed during IVP, video-urodynamics, or radioisotope studies [6].

Catheterization is the gold standard for measuring PVR. However, it should be noted that proper technique is important to obtain an accurate measurement [24]. Moving the catheter in-and-out and twisting may be important to ensure proper collection of any urinary residual in the bladder [25]. However, this is an invasive procedure that carries some risk of infection and is associated with some discomfort to the patient. Alternatively, portable ultrasound scanners with automated measurement of bladder volume are non-invasive, more comfortable to the patient, and easy to use. They can be used with reasonable accuracy [26].

Based on the 4th International Consultation on Incontinence, ultrasound is the recommended means for measuring PVR as it is the least invasive and is sufficiently accurate for clinical practice [6]. Several measurements should be considered due to intra-individual variability [6, 10, 24, 27]. The PVR reading should be performed as soon as possible after the patient voids to avoid erroneous readings. A delay in performance of the test following a volitional void will result in additional urine accumulation in the bladder which can result in an inaccurate PVR determination. Urine is added to the bladder at a rate of approximately, 1–14 mL/min [28].

There is no standardization on what is considered a normal PVR. Some would argue that less than 50 mL is considered normal in adults [29] and others would consider the upper limit of normal to be 100 mL [28]. However, if the patient is asymptomatic then they may not need treatment even with PVR's in excess of 100 cc depending on the clinical situation and clinical judgment [30]. A consistently elevated PVR is an indication of possibly impaired detrusor contractility or bladder outlet obstruction (or both) and such a finding warrants more in depth investigation.

Voiding Diary (Frequency–Volume Charts)

This is a simple non-invasive test to evaluate patients with LUTS and voiding dysfunction in his/her natural environment and during regular daily activities [31]. The diary evaluation consists of recording the time and volume of each void over 24 h. ICS considers a 24-h properly performed diary as a reasonable evaluation tool for clinical practices [32]. However, a diary for 3 days is preferred for proper assessment and to avoid skewing of the data obtained by spurious behavior on a single day [32]. The diary does not need to be on consecutive days. It is important to note that simply performing the diary may alter the patients' normal behavior.

A voiding diary (frequency–volume charts) should be considered as part of the initial evaluation of patients with LUTS especially those who have frequency and nocturia. The diary helps to establish a quantitative baseline for the symptoms such as frequency and urgency as well as voided volumes and subsequent diaries allow monitoring of sequential therapies over time [27]. Information obtained from a diary includes voiding frequency, nocturia, amount of urine voided in 24 h and overnight, average voided volume, median functional bladder capacity, number and timing of incontinence episodes, and urgency. It is the only tool to diagnose polyuria [20] and nocturnal polyuria (Table 5.3 and 5.4). It is very important to stress to the patient that the diary should be performed on a regular ordinary day that represents their usual routine.

It is very helpful to have the voiding diary prior to performing the multichannel UDS study. This will provide an estimate of the functional bladder capacity, which will allow the UDS to be customized with respect to filling rate and expected bladder capacity. Additional information can be acquired from the diary including the episodes of urgency and urine leakage that could be correlated to involuntary detrusor contractions (IDCs) on the UDS study.

Table 5.4 Information can be obtained from voiding diary and definitions

Information obtained	Definitions
Diurnal frequency	Number of voids during the day (wakeful hours)
Nocturia	Number of times of voids interrupt the sleep and each void is preceded and followed by sleep
24-h urinary frequency	Number of diurnal frequency and nocturia
Maximum voided volume	Maximum voided volume recorded
Average voided volume	The sum of voided volume during 24 h divided by the number of voids
Small voided volumes	Suggest OAB or a pathology results in decrease of bladder volume such as inflammatory process or contracted bladder
Median functional Bladder capacity	Median maximum voided urine in the 24-h activity
Polyuria	Excessive urine production resulting in increased urinary frequency. It is defined as increased urine production more than 40 mL/kg/day. Voiding diary will show increased urine output associated with increased frequency
Nocturnal urine volume	Total volume of urine voided after going to bed for sleeping including the first morning void with intention of rising
Nocturnal polyuria	More than 20–33 % (depending on age) of total urine production is excreted at night

There are multiple voiding diaries available on different websites. Examples of websites containing diary examples include the Society of Urodynamics, Female Pelvic Medicine and Urogenital Reconstruction (SUFU) (<http://www.sufuorg.com/docs/patient-resources/SUFU-voiding-diary.aspx>), The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) (http://kidney.niddk.nih.gov/kudiseases/pubs/diary/diary_508.pdf), and the International Urogynecological Association (IUGA) (http://c.ymcdn.com/sites/www.iuga.org/resource/resmgr/brochures/eng_bladderdiary.pdf). Table 5.5 is the diary used in our institution.

Pad Test

For patients with urinary incontinence, a pad test is an important tool for the detection and quantification of urine loss over a set period of time. It is an objective test that can be performed by the patient and can help to quantitate urine leak. A properly done pad test will enable the physician to have a realistic idea about the severity of incontinence [33]. This also may aid to design and individualize the UDS study [4]. For example, in a patient with a complaint of urinary incontinence as well as incontinence noted on the voiding diary and pad test, every effort should be made to reproduce these symptoms during the UDS study. If a symptom is not reproduced initially during the study, then provocative maneuvers should be performed in order to elicit such a finding.

Table 5.5 Voiding diary adopted in our institution

Name _____

Date _____

Time of Day	Amount of urine Voided (oz or ml)	Amount of Fluid (Drinks) Intake (oz or ml)	Type of Fluid Consumed (water, coffee, soda, beer, etc.)	Urgency Or Pain Before Voiding? (yes or no)	Leakage of Urine (incontinence) at any time prior to Voiding (yes or no)
7am					
8am					
9am					
10am					
11am					
12 noon					
1pm					
2pm					
3pm					
4pm					
5pm					
6pm					
7pm					
8pm					
9pm					
10pm					
11pm					
12 am					
1 am					
2am					
3am					
4am					
5 am					
6am					
Total for 24 hours					

Please indicate the time that you went to bed: _____

Please indicate the time that you woke up: _____

Ideally the pad test should be performed while the patient is performing everyday regular activity. Pad tests have been described for multiple lengths of time from 1 to 24-h and 48-h up to 1 week [16]. The standardized 1-h pad test entails the patient drinks a volume of 500 mL of sodium-free fluid over a short period of time and then engages in a standard set of maneuvers over a 1-h period [4]. The 1-h pad is then collected and weighed. The ICS 1-h pad test upper limit of normal is >1 g [4, 32]. A 24-h pad test is an alternative assessment which offers to be a more practical assessment of patient leakage [4, 33]. The normal upper limit for a 24-h pad test is 4 g [32].

Investigations

Urinalysis

Urine should be tested on the day of the UDS study. If there is evidence of infection, then the UDS test should be postponed. If a patient has a history of repeated urinary tract infection or a high risk of infection, then the appropriate antibiotic coverage should be considered prior to the study [5, 34].

Provided that the patient is asked to void prior to the start of the UDS study, a catheterized urine specimen at the start of the study as the UDS catheters are placed provides an assessment of PVR and a clean urine specimen for testing. Urine can be tested using dipsticks or microscopy. A urine culture is obtained if indicated [4, 15].

Urine Cytology

Cytological studies of urine may be indicated in some patients including those with a history of LUT tumors, or pronounced storage symptoms such as increased urinary frequency, urgency, and hematuria. [20]. In postmenopausal women with LUTS, the hormonal status may affect the vaginal wall and result in LUTS. In such cases, a lateral vaginal wall cytology smear may help to diagnose estrogen deficiency [20].

Imaging

Upper urinary tract imaging is not recommended for patients with LUTS except in certain circumstances. The indications for upper tract imaging as recommended by the 4th International Consultation on Incontinence [6] include

1. Hematuria
2. Neurogenic urinary incontinence
3. Severe pelvic organ prolapse
4. The presence of flank pain
5. Questions about the possible presence of extra-urethral incontinence.
6. Diagnosed low bladder compliance
7. Children with UTI associated with incontinence

Antibiotic Prophylaxis

The risk of developing bacteruria after UDS testing in adults varies from 6.2 to 13.9 % [35, 36] and the incidence of urinary tract infection following multichannel UDS evaluation is rare and varies from 2.1 to 6.9 % [37–39]. Antibiotic prophylaxis

helps to reduce bacteruria by 40 % but this is not reflected by a reduced incidence of urinary tract infections [40]. Therefore, routine administration of antibiotic prophylaxis is not recommended. However, it may be reasonable to use in patients with risk factors for bacteruria after UDS testing [41]. These risk factors include recurrent urinary tract infections, diabetes mellitus, neurogenic bladder, and recent history of urologic or urogynecologic surgery [35, 39].

Starting the UDS Study

Patient Positioning During the Study

Multichannel UDS studies may be performed in the seated, standing, or supine position. In performing multichannel UDS, one should consider conducting the study in the position in which the patient usually experiences their symptoms. For example the standing position would be the most likely position to reproduce the patient's symptoms of SUI [4]. Al-Hayek et al. [42] in a meta-analysis found that detrusor overactivity (DO) is elicited at a higher incidence in the vertical position (standing or sitting) or when changing to a vertical position. Performing the study in a supine position would have missed diagnosing DO in 33–100 % of patients.

The International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report recommends performing the UDS study in the sitting position as this will be more provocative to uncover DO than the supine position. They also recommended performing the study at some point with the patient in the standing position [20]. During voiding, the patients should be placed in the usual position that they assume while voiding to simulate ordinary circumstances [18]. Changes in the patient's posture during the study should also be noted as this will result in artifacts which should be accounted for during interpretation [4, 18].

Filling the Bladder

Filling Rate

Bladder filling can be performed using either single lumen catheters or dual lumen catheters. Single lumen catheters may provide a larger caliber lumen for filling. However, such a technique will require insertion of an additional catheter for measuring pressure inside the bladder. Two catheters in the urethra may increase the probability of occluding the urethra and masking some of the UDS findings especially SUI [4]. Dual lumen catheters are recommended by the International Continence Society (ICS) to perform the dual functions of bladder filling and simultaneous recording of intravesical pressure. It is recommended to use the smallest catheter that:

1. Allows an adequate rate of filling.
2. Does not compromise voiding and cause artifact (false obstruction or mask SUI)
3. Does not affect pressure transmission

Filling rates are variable and can be *slow* (10 mL/min), *medium* (10–100 mL/min), or *fast* (>100 mL/min). A medium filling rate is most suitable for most patients. However, faster rates are used as provocative maneuvers to elicit detrusor overactivity (DO) in patients with OAB symptoms. The physiologic rate of filling can be calculated at a rate less than 1/4 of the total body weight in mL/min [43]. At this rate of filling the pressure–volume curve continues to be flat and detrusor pressure changes are related to volume rather than rate [43].

Type of Filling Medium

Fluid medium is preferred over gas and is recommended by ICS for filling [28]. Sterile water, normal saline, or contrast medium can be used for filling [4, 28]. Care should be taken to avoid changing between fluids during the study as calibration will be affected and will result in inaccurate filling volumes. Gas (CO₂) has been used as a filling medium [44], however it does not have the same density as fluid medium. Thus it does not mimic urine which is fluid in nature. Finally, fluid allows for assessment of uroflow during voiding which is not possible with gas.

Temperature of the Medium

Ideally, the temperature of the filling solution should be compatible with body temperature. However, in practice this is often difficult. Infusing fluid at room temperature is appropriate in this setting. On the other hand, cold fluid should be avoided as this can activate aberrant neural pathways and reflexes which may precipitate clinically insignificant IDCs and bladder sensations [4].

Interpretation of UDS Study

Physicians must interpret UDS results in the context of the general assessment of the patient. Interpretation of UDS results should be integrated with and complement all the available information obtained from a complete history, neuro-urological examination, voiding diaries, pad tests, and other work-up deemed clinically relevant. Interpreting a UDS study result out of the context of the clinical scenario could be misleading [10].

Analysis of the UDS test should include not only a full evaluation of the actual graph and images, but also should incorporate observations made during the study [13, 14]. If the physician is not performing the study by himself/herself, such information should be communicated to the physician by the technician performing the study. These observations should reflect any patient behaviors and activities during the study. Any alterations on the graph associated with changes in position, talking, voiding, or pushing to void should be noted and recorded. If these artifacts are not properly labeled and pointed out on the graph, they can be misread and can result in inappropriate and misleading conclusions.

Another important point is that during interpretation, the physician should acknowledge that UDS testing is performed while the patient is in an awkward situation. This is associated with minimal to moderate degrees of anxiety, discomfort, and embarrassment which could result in artifacts during the study [45].

Challenges Facing the Physician During UDS Interpretation

To obtain a meaningful interpretation of the UDS findings, the physician should always recognize the presence of multiple challenges during testing. One should think about factors that can affect the outcome of the study. Such factors should be accounted for while performing and interpreting the UDS study [18]. These factors can be related to place, patient, and/or practitioner.

1. *Place of the study*: It is not always easy to create a suitable and natural environment for the patient during the study, which is by nature an uncomfortable and unnatural situation for the patient. The patient is being exposed in front of strangers and is asked to void, an inherently private bodily function, in front of others, which could be extremely sensitive and could alter their natural behavior leading to potentially abnormal and clinically irrelevant findings [18]. In addition the anxiety produced by this situation can result in an aberrant reaction of the patient resulting in “Shy bladder syndrome” or psychogenic inhibition of voiding, which is associated with social anxiety. [46].
2. *Patient factors*:
 - a. *Position of the patient*: Patients are positioned during the study as dictated by the study scenario. However, this is often different from the position wherein the patient ordinarily experiences urinary symptoms. Different positions are associated with pressure changes within the bladder and can alter the bladder behavior unexpectedly during the study. In the setting where the patients symptoms are not reproduced during the UDS study initially, one should consider asking the patient about their position when they usually experience their symptoms and repeat the study in that position.
 - b. *Tubes (urethral catheter and rectal transducer)*: Catheters that are used during the multichannel UDS study include, most often, one urethral and the other rectal. Although they are small in diameter they can be painful and bothersome to the patient. Pain may result in external sphincter spasm as well as inhibit the micturition reflex. These effects can result in an artifactual inability to void during the study due to pain, as well as changes in urine flow [47] and mask stress urinary incontinence [9].
 - c. *Filling the bladder*: The solution utilized to fill the bladder is not urine and therefore the study is performed with a medium that is non-physiologic in composition, filled at a non-physiologic rate, and most often at a non-physiologic temperature (room temperature). These factors can affect bladder sensation and response during filling [18]. If the patient is showing unexpected findings, these factors should be considered as potential sources for artifact or aberrant findings.

3. *Practitioner interpreting the results:* [48, 49] Identifying artifacts is critical in interpreting multichannel UDS studies accurately. It is imperative to stress the importance of accurately and appropriately labeling events on UDS tracings. Reviewing the UDS tracing and numbers recorded during testing is an important part of interpretation and one should not depend on the computer analysis only to detect artifacts that could occur during the study [10]. It should be kept in mind also while performing the study and during interpretation that the study represents only a momentary glimpse of the patient's normal voiding habits and does not reflect the long-term and variable patterns often seen over time in any given individual.

Conclusion

UDS are an important tool in the evaluation of patients with LUTS and voiding dysfunction. UDS provides an objective evaluation of the patient's presenting LUTS which are often "unreliable" in predicting the underlying urodynamic and physiologic findings. UDS are often aimed at the characterization of LUT dysfunction, and assessing risk factors that can lead to kidney deterioration. UDS testing also may help to assess the possible outcomes of expected treatment and possible causes of previous treatment failures. However, the UDS studies do not replace an adequate work-up including proper history, physical examination, and other appropriate tests.

Reliable UDS results depend on the proper design, performance, and interpretation of the study. Patient counseling may help prevent or minimize problems that may arise during the study. Setting up a proper environment and having well-trained and experienced personnel is paramount for an optimal study. Excellent communication between the nurse or technician who is performing the study, and the patient, as well as the physician interpreting the study helps to minimize artifacts during interpretation. It is important to understand that UDS should be utilized and interpreted within the context of the patient's entire clinical picture and should not be isolated from the rest of the evaluation process.

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