Basic understanding of urodynamics

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Abstract

Urodynamic investigations are an important tool aiding the clinical management of patients with lower urinary tract symptoms, such as overactive bladder, urinary incontinence, and voiding dysfunction. Urodynamic investigations can be non-invasive or invasive. Non-invasive tests include uroflowmetry and ultrasound measurement of post-void residual urine volumes. Invasive tests involve urethral catheterization to measure bladder pressure, and placement of a catheter either in the vagina or the rectum to measure abdominal pressure. The detrusor pressure is obtained by subtracting abdominal pressure from bladder pressure. Invasive urodynamics carry a low risk of urinary tract infection. The International Continence Society has published standards on good urodynamic practice and the terminology of lower urinary tract function. Urodynamic investigations should be performed by a trained clinician who can understand urodynamics on a physical and technical level, as well as the physiology and pathophysiology of the lower urinary tract.

Keywords catheterization; cystometry; urodynamics

Introduction

The term *urodynamics* refers to tests which are used to investigate lower urinary tract (LUT) symptoms, by measurement of bladder and urethral function both directly and in-directly. This article focuses on urodynamics performed in women. Indirect assessment of LUT function is performed through non-invasive investigations, such as uroflowmetry, bladder ultrasound, and completion of bladder diaries. Direct assessment of LUT function is performed through invasive techniques which require catheterization of the bladder, and placement of an abdominal pressure catheter in the vagina or rectum. The term urodynamics has become almost synonymous with *cystometry* by clinicians, which refers to direct measurement of pressure during bladder filling and voiding. The aims of urodynamics are to reproduce patients' symptoms, and to provide a pathophysiological explanation to help direct management.

The International Continence Society (ICS) standardises the terminology of LUT function and sets out guidelines for 'Good Urodynamic Practice'. The United Kingdom Continence Society (UKCS) has also agreed minimum standards for urodynamic studies (2018). These guidelines should be adhered to by any person performing urodynamics to enable standardization across institutions. Patients must receive clear and unambiguous information about the investigation prior to undergoing urodynamics.

Establishing the urodynamic question

Patients often present with multiple LUT symptoms. The "urodynamic question" should be identified before performing any investigation. It outlines the patients' symptoms that require diagnosis and determines which urodynamic investigation is appropriate to be able to answer this question. Many women who attend the urogynaecology clinics present with storage symptoms, including incontinence and/or urinary urgency, hence cystometry would be the appropriate test.

The "urodynamic question" is formulated from an initial physical examination (including abdominal, pelvic, and perineal), a focussed neurological examination, and a comprehensive clinical history. The clinical history should include any concerning urinary symptoms (for example nocturia, increased daytime frequency, and incontinence episodes), their duration, and their effect on quality of life. Relevant past medical history should be noted, including surgical and obstetric history, and neurological disease. A list of current medication should be noted. Instructions must be given to the patient regarding (dis) continuation of usual LUT management (i.e., medication) prior to testing.

A frequency/volume chart (FVC) or a bladder diary (BD) should be completed prior to urodynamics. The FVC records the time of each micturition and the volume voided for at least 24 hours. A bladder diary should be completed for three full days (consecutively or non-consecutively) and, in addition to the information obtained on a FVC, should include fluid intake, pad usage, incontinence episodes, and the degree of incontinence. It may also include episodes of urgency and/or sensation, and the activities performed during or immediately preceding the involuntary loss of urine. Important information such as daytime frequency, nocturia, (nocturnal) polyuria, maximum voided volume, and excessive fluid intake can be determined from the FVC or BD. It can often be challenging if the patient is non-compliant with completing a FVC or BD as the information gained aids plausibility control of subsequent urodynamic studies. It can be used to estimate functional bladder capacity and bladder volumes at which the patient's symptoms are likely to be reproduced (i.e., preventing over-filling the bladder during conventional urodynamics).

Urodynamic equipment

Uroflowmeters

Generally, two types of flowmeter exist in clinical practice: the gravimetric (load cell) flowmeter, and the rotating disk flowmeter. The gravimetric flowmeter measures the weight of urine with respect to time, to obtain flow rate. With the rotating disk, urine flow impedes the rotation of the disk to determine flow rate, and this can be integrated to obtain the voided volume. The gravimetric (load) cell flowmeter is more commonly used in clinical practice.

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Transducer and catheter systems

There are three types of transducer and catheter systems used in clinical practice:

1) Fluid-filled catheters and external transducers
2) Catheter-tip transducers
3) Air-charged catheters and external transducers

Current ICS guidelines recommend performing cystometry with a fluid-filled system and external transducers as it has been widely studied and is well-understood. A fluid-filled catheter is passed to the measurement site and attached to an external transducer which is levelled to the upper edge of the symphysis pubis as an anatomical landmark for the bladder. The position of the catheter tip within the bladder is not concerning due to the continuous column of fluid along the catheter. Fluid-filled systems are sensitive to high frequency artefactual signals from patient movement making the urodynamic traces more difficult to interpret. Positional changes of the patient, i.e., supine to standing, requires re-alignment of the external transducers to the upper edge of the symphysis pubis and therefore the equipment must have scope to accommodate this. Air-bubbles in a fluid-filled system can dampen pressure signals and the catheters must be flushed prior to starting the investigation.

Catheter-tip transducers have a transducer mounted in the tip of the catheter. These catheters measure pressure at their tip and do not require an external transducer set up. The position of the catheter inside the bladder will affect pressure measurement (i.e., pressure measured at the top of the bladder can be 10 cmH_2O lower than at the bladder base). Catheter-tip transducers generally exhibit fewer artefacts than fluid-filled systems with external transducers. Catheter-tip transducers are not single use and require sterilization between patients which can be timely and costly.

Air-charged catheters are disposable and are filled with air, with a small compliant micro-balloon covering the opening at the end (at the site of pressure measurement). The catheters are connected to external transducers. Pressure transmitted onto the 'charged' balloon at the tip is conveyed through the air-filled catheter to the external transducer. The frequency response of air-charged catheters is slower than fluid-filled catheters when pressures change rapidly (i.e., during coughing). They are less susceptible to high frequency artefactual signals than fluid-filled catheters. There is no concern over placement of the catheter in the bladder affecting pressure measurement which allows patients to move around freely during the investigation. Air-charged catheters are less widely researched and understood in comparison to the fluid-filled system.

Urodynamic investigations

Urodynamic investigations include:

- Uroflowmetry and measurement of post-void residual (PVR) urine volumes
- Cystometry (conventional urodynamics)
- Ambulatory urodynamics
- Videocystometry
- Urethral pressure measurements

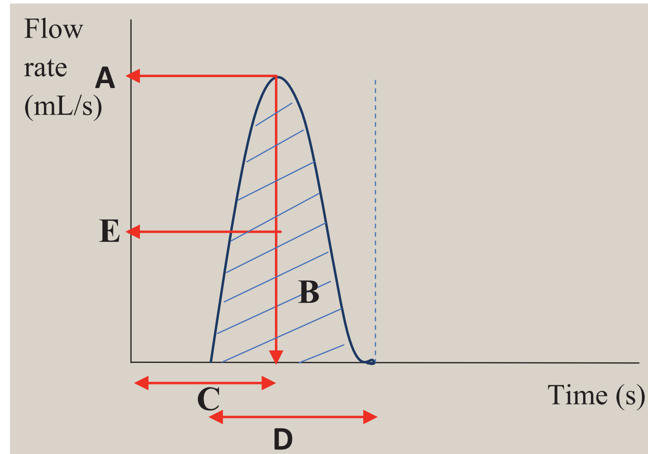

Figure 1 Example of a flow curve. Typical parameters measured by uroflowmetry include: (**a**) maximum flow rate (Q_{max}); (**b**) voided volume (V_{void}) (area under the curve); (**c**) time to maximum flow (T_{qmax}); (**d**) flow time (s): time over which measurable (non-intermittent) flow occurs, (**e**) average flow rate (Q_{ave}): voided volume divided by voiding time and (**f**) voiding time (not shown on diagram): total time taken to void, inclusive of breaks in intermittent flow. ICS definitions of terms are given in Box 1.

Uroflowmetry

Uroflowmetry is used as a first line investigation for the assessment of voiding dysfunction. Patients void into a flowmeter when they feel the desire, in a comfortable and adequately private environment. This ensures the void has been representative, and only then should it be clinically interpreted. The rate and pattern of urine flow should be analyzed and may provide an indication of detrusor activity, and resistance to flow. The flowmeter measures the volume or mass of urine passed per unit time in millimetres per second (ml/s) which is represented as a graphic recording of flow rate versus time (Figure 1, Box 1). Urinary flow is affected by detrusor contractility, bladder outflow resistance, and bladder volume. Voided volumes over 125 −150 mls are necessary to ensure that uroflowmetry curves are reliable and accurate. The normal female maximum flow rate should be more than 15 ml/s with a 'bell-shaped' curve and a PVR of less than 30 ml measured by non-invasive ultrasound scanning of the bladder or urethral catheterization.

Uroflowmetry evaluates the nature of an individual's voiding pattern and can identify problems with bladder emptying. Figure 2 shows an example of poor voiding on uroflowmetry. Results should be compared with the FVC or BD to assess the correlation of findings with symptoms, and to ensure that the void has been representative of a private void in the home setting (i.e., the patient has voided at their normal bladder capacity).

Cystometry (conventional urodynamics)

Clinical indications: conventional cystometry is not indicated if stress urinary incontinence or stress-predominant mixed urinary incontinence is diagnosed based on a detailed clinical history and demonstrated at examination.

ICS definitions of terms used in uroflowmetry

Flow rate is the volume of fluid expelled via the urethra per unit time (ml/s).
Maximum flow rate is the maximum measured value of the flow rate after correction for artefacts
Voided volume is the total volume expelled via the urethra
Time to maximum flow is the elapsed time from onset of flow to maximum flow
Flow time is the time over which measurable flow actually occurs
Average flow rate is voided volume divided by flow time. The average flow should be interpreted with caution if flow is interrupted or there is a terminal dribble

Box 1

Conventional cystometry is indicated before surgery for stress urinary incontinence in women who have any of the following:

- Urge-predominant mixed urinary incontinence or urinary incontinence in which the type is unclear
- Symptoms suggestive of voiding dysfunction
- Anterior or apical prolapse
- A history of previous surgery for stress urinary incontinence

Conventional cystometry may also be indicated in women prior to invasive treatment for overactive bladder (OAB) e.g., Botulinum toxin A (BTXA) or sacral nerve stimulation (SNS).

Risks of conventional cystometry: invasive urodynamics involves urethral catheterization and thus the subsequent risk of urinary tract infection (UTI) of between one and 10%. Most centres do not advocate the routine use of antibiotic prophylaxis for cystometry unless indicated (i.e., patients with an indwelling catheter or performing clean intermittent self-catheterization). Dysuria (painful voiding) occurs in some patients after urodynamic testing, which typically resolves within 48 hours.

Coexisting urine infection could be exacerbated by catheterization and artificial bladder filling (e.g., development of pyelonephritis) and may lead to inaccurate results. A urine dipstick test should be performed before proceeding with conventional cystometry to exclude urinary tract infections and haematuria, which can present with LUT symptoms. Urine dipstick test should be examined for the presence of nitrites, leukocytes, protein, and blood in urine, and the patient should be clear of

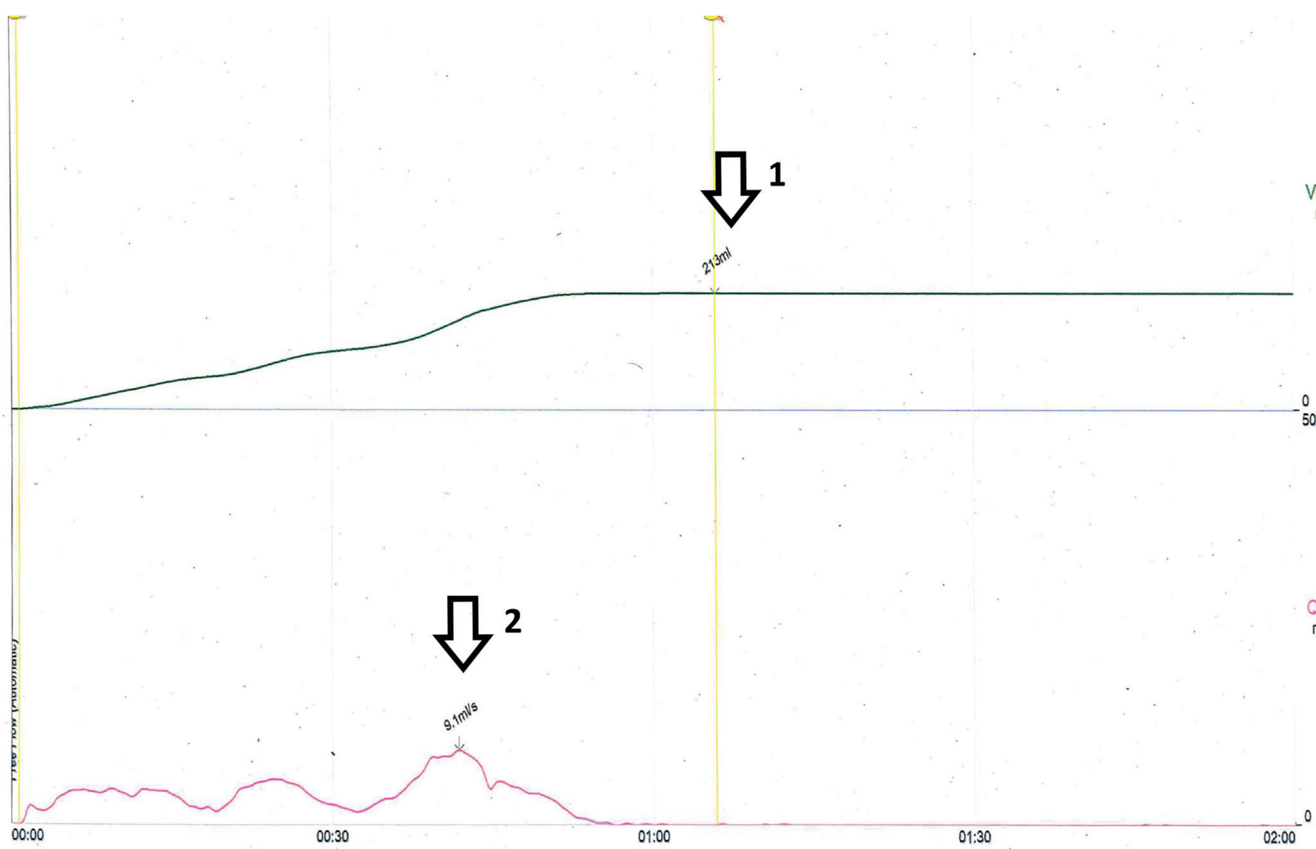

Figure 2 Example of poor voiding on uroflowmetry. Arrow 1 indicates the voided volume (V_{void}): 210 mls (voided volumes are rounded to the nearest 10 mls). This volume is sufficient for clinical interpretation. Increasing bladder volume increases the potential bladder power, notable in the range from empty up to 150–250 mls. At volumes higher than 400–500 mls, the detrusor may become overstretched and contractile strength may decrease. Arrow 2 indicates the maximum flow rate (Q_{max}): 9 mL/s (rounded to the nearest whole number) which indicates poor flow. The Q_{max} should typically be reached within 5 seconds from the start of flow, however it takes 41 seconds for the Q_{max} to be reached on this void. The flow curve does not follow a typical 'bell-shaped' appearance; the flow appears to be fluctuating and does not demonstrate a rapid fall from high flow or a sharp cut-off at the termination of flow. Poor voiding may reflect reduced contractility of the detrusor muscle or obstruction to flow, however this can only be determined by intravesical and intra-abdominal pressure measurements on cystometry.

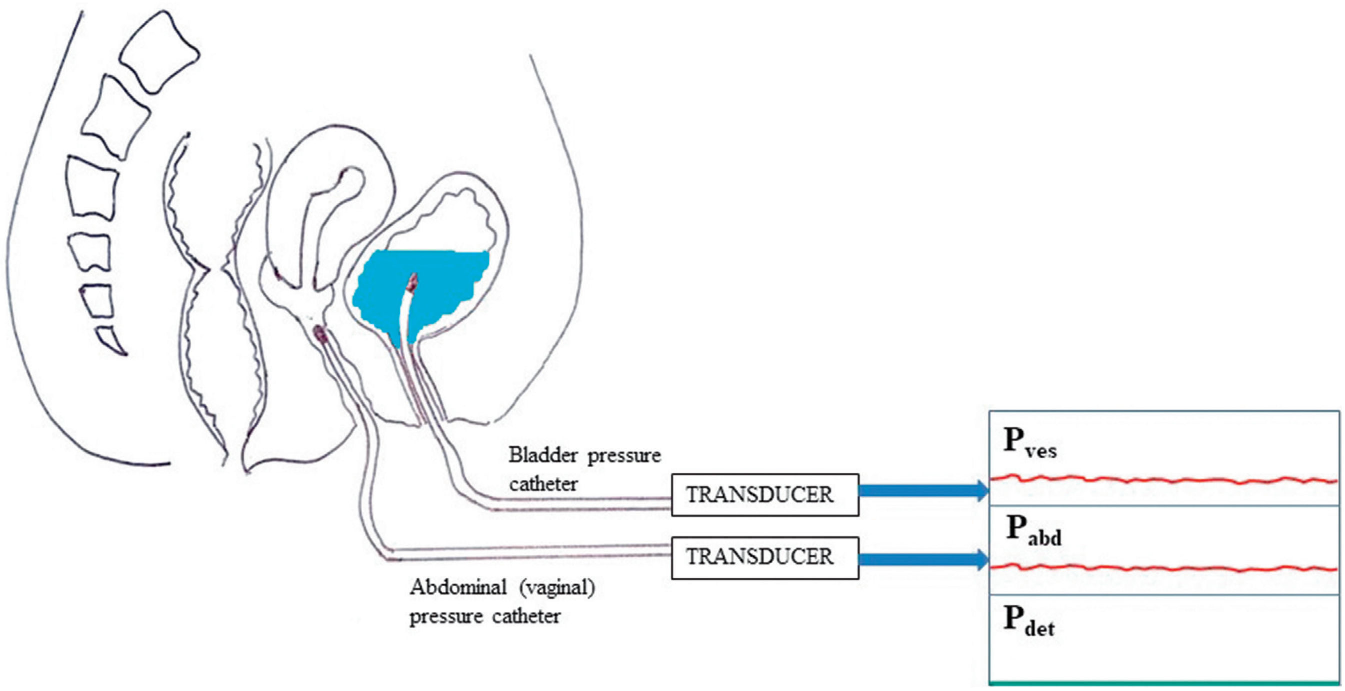

Figure 3 Illustration of abdominal and intravesical catheter placement and pressure measurement in a female. Note that the detrusor pressure (P_{det}) is obtained by subtracting abdominal pressure (P_{abd}) from intravesical pressure (P_{ves}). The bladder is filled with saline either using a dual lumen intravesical catheter, or a separate second filling catheter.

infection. Haematuria present in urine may warrant further investigation (e.g., cystoscopy) to identify its cause.

Filling cystometry: medication used to treat symptoms of OAB are typically stopped 72 hours prior to urodynamic assessment/cystometry. However, if a patient presents with mixed urinary incontinence symptoms and the urge urinary incontinence is well controlled with medication, the test may be performed on medication to confirm the presence of stress urinary incontinence.

Filling cystometry involves placing a transurethral catheter (by aseptic non-touch technique) into the bladder to measure intravesical pressure (P_{ves}). Intravesical pressure can be measured using catheters through alternative routes e.g., suprapubic or mitrofanoff. Abdominal pressure (P_{abd}) can be measured by inserting a catheter into the vagina, rectum, or stoma. The intravesical pressure has contributions from the bladder detrusor muscle and abdominal pressure, therefore it is necessary to subtract the abdominal contribution from the intravesical pressure to ascertain a true detrusor pressure (P_{det}) (measured in centimetres of water; cmH_2O) (Figure 3).

Filling cystometry is usually performed in the seated or upright position whenever physically possible. The bladder is filled with saline (warmed to body temperature), either by a separate filling line or by use of a dual lumen vesical catheter. Typically, the bladder is filled at a rate that is higher than a maximum physiological filling rate (50−100 ml/min) to be able to perform the investigation in a timely manner. A reduced bladder compliance is a potential consequence of using a non-physiological filling rate and filling should be stopped in these circumstances to observe detrusor pressure. If the detrusor pressure reduces back to baseline values, the pressure is likely increasing due to the filling rate.

Filling should be stopped when the patient is no longer able to delay micturition (maximum cystometric capacity; typically between 400 and 600 mls), or if severe incontinence is observed. Throughout the filling phase, there should be little or no change in detrusor pressure. The filling rate may be reduced or paused if the patient experiences urgency or pain at low bladder volumes.

Reporting sensations: patients are required to report bladder sensations throughout the filling phase, and this should be made clear to the patient before starting the investigation. The ICS guidelines recommend recording three sensations:

- First sensation of filling (FSF)
- First desire to void (FDV)
- Strong desire to void (SDV)

Patients may additionally report sensation(s) considered to represent urgency or pain. It is necessary to record patients' symptoms contemporaneously on the trace to correlate symptoms with physiological findings. For example, urgency may be felt by the patient if they are experiencing detrusor overactivity (DO), and this should be recorded at the specific time on the trace.

Provocation phase: the provocation phase is useful in demonstrating provoked DO or urodynamic stress incontinence (USI) (Figure 4). The provocation phase is undertaken with the bladder at maximum cystometric capacity. Provocative manoeuvres can include coughing, heel bounces, postural changes (e.g., lying to standing), running water, and handwashing.

Voiding cystometry: the voiding phase should commence only once the patient has been given permission to void onto the flowmeter, with the catheters *in situ*, unless the patient is experiencing severe detrusor overactivity incontinence in which case the bladder

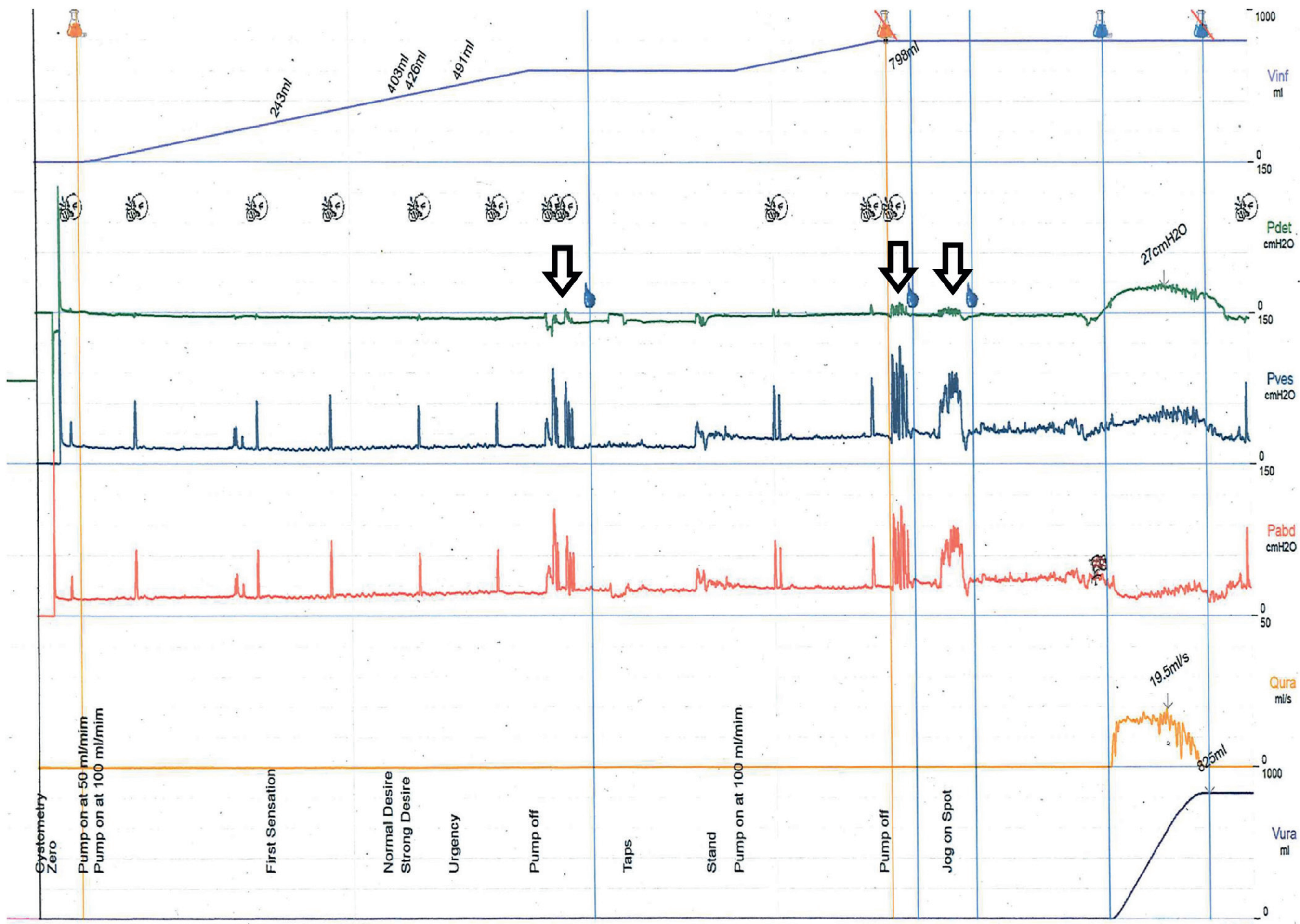

Figure 4 A conventional cystometry study demonstrating urodynamic stress incontinence. The simultaneous rises in intravesical pressure (P_{ves}) and abdominal pressure (P_{abd}) are due to coughing and jogging on the spot. Note that the detrusor pressure (P_{det}) remains stable during the provocation phase (denoted by the arrows on the trace). The patient experiences urinary leakage during coughing in the supine and standing positions, and whilst jogging on the spot (urodynamic stress incontinence).

may have been emptied uncontrollably. If two single lumen catheters have been used during the filling phase, the filling catheter is removed prior to voiding. If a double lumen catheter (with two channels; one for filling and one for pressure measurement) has been used it must remain *in situ*. The patient should be left in an adequately private setting to complete a void which is representative of their 'normal' void. A pressure-flow recording is made during the void. Particular attention should be paid to certain parameters; total voided volume (V_{void}), detrusor pressure at maximum flow rate ($P_{detQmax}$), flow pattern, and any evidence of straining. A cough should be recorded immediately after the voiding phase to ensure pressure measurement and catheter placement have not been affected by the void. Catheters can be removed after the patient has completed an adequate void and the PVR urine should be measured immediately after the patient has finished voiding.

Urodynamic diagnoses

Detrusor overactivity and urodynamic stress incontinence

Two common diagnoses on conventional cystometry are DO and USI. DO is characterized by involuntary detrusor contractions during the filling phase which may be spontaneous or provoked (Figure 5). DO may or may not lead to incontinence however it is typically associated with urgency. There is no lower limit for the amplitude of an involuntary detrusor contraction however confident interpretation of low-pressure waves (amplitudes less than 5 cmH_2O) depends on "high quality" urodynamic technique (i.e., low-pressure waves are not attributed to artefact or movement). DO can be phasic or terminal. Phasic DO is defined by a characteristic waveform (Figure 5). Terminal DO is defined as a single, involuntary detrusor contraction occurring at cystometric capacity, which cannot be suppressed and results in incontinence usually resulting in bladder emptying.

USI is observed during the filling and provocation phases of cystometry and is defined as the involuntary leakage of urine during increased abdominal pressure, in the absence of a detrusor contraction (Figure 4).

Abdominal/valsalva leak point pressure (ALPP/VLPP)

The ICS defines the ALPP/VLPP as the intravesical pressure at which urine leakage occurs due to the increased abdominal pressure in the absence of a detrusor contraction. The ALPP and VLPP can be ascertained by asking the patient to cough or to

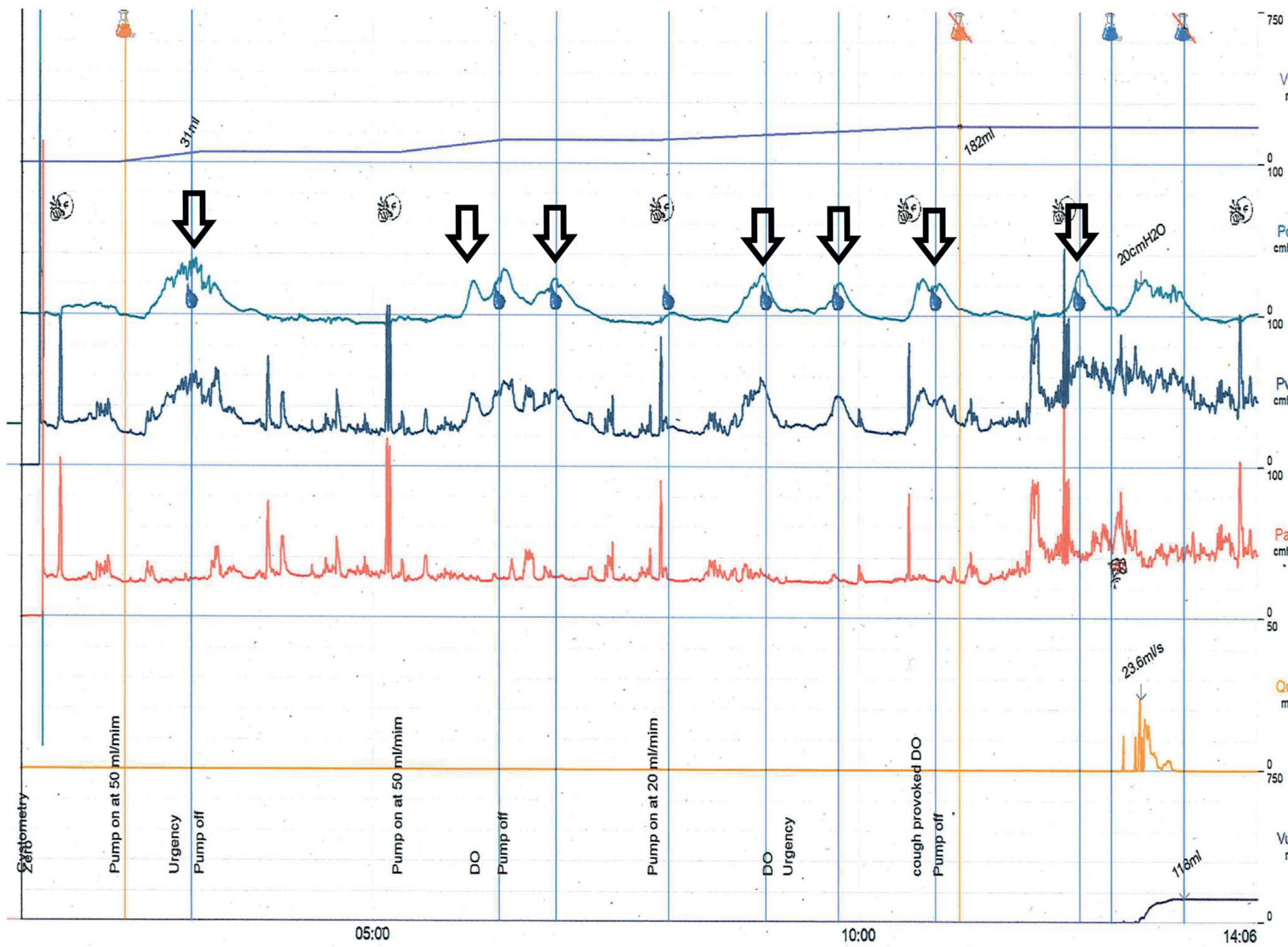

Figure 5 A conventional cystometry study demonstrating detrusor overactivity incontinence. Note the phasic rises in detrusor pressure (P_{det}; denoted by arrows on the trace) due to increased intravesical pressure (P_{ves}) whilst abdominal pressure (P_{abd}) remains stable with only minor fluctuations in pressure related to movement.

perform a valsalva manoeuvre, respectively. Using a cough to increase abdominal pressure can induce a sudden increase in abdominal pressure which can interfere with measurement. Additionally, the technique assumes that the urethral catheter used for the test does not significantly alter the seal of the urethra, and that straining does not produce urethral distortion. VLPP may be used to help distinguish between intrinsic sphincter deficiency (ISD) and urethral hypermobility (UH). A VLPP less than 60 cmH_2O is thought to represent ISD, VLPP between 60 and 90 cmH_2O is said to be equivocal, and VLPP more than 90 cmH_2O suggests UH.

Detrusor leak point pressure (DLPP)

The DLPP is defined as the lowest detrusor pressure at which urine leakage occurs in the absence of either a detrusor contraction or increased abdominal pressure. DLPP is ascertained by recording the detrusor pressure at the point that leakage occurs during the filling phase of cystometry. This measurement may be useful in the assessment of patients with poor bladder compliance whose upper urinary tracts may be at risk from high-pressure filling e.g., patients with neurogenic bladder dysfunction. A high DLPP is correlated with a higher risk of upper urinary tract pathology.

Calibration of pressure transducers

The ICS has published guidelines on urodynamic equipment performance (2014). Pressure transducer calibration is achieved by exposing the catheter tip, or sensor, to two different well-defined pressures (a pressure difference of more than or equal to 50 cmH_2O is recommended). Calibration of pressure measurement systems should be verified regularly, for example, once every 10 urodynamic measurements. Calibration can be checked by applying a known pressure to the transducers or raising the catheter to a known height (dependent on the type of system) to ensure the transducers are reading the correct pressure. If pressure readings are more than 2 cmH_2O different from the applied pressures, recalibration of the system is necessary.

Quality control

Urodynamic investigations should be performed in a safe and scientific manner. It is imperative that the clinician performing urodynamics understands the tests on 1) a physical and technical level, 2) a biomechanical level, and 3) a pathophysiological clinical level. The ICS has published guidelines for good urodynamic practice. Some of the most important aspects are summarized below:

- Reference height: The reference height level is the upper edge of the symphysis pubis. External transducers used in fluid-filled systems should be placed at this level.
- Zero pressure: Zero pressure is the ‘surrounding atmospheric pressure’ i.e., when the transducer is open to the environment. The vesical and abdominal lines should be zeroed to atmosphere before starting the investigation.
- Resting values for abdominal and intravesical pressure: These values are the excess pressure above atmosphere and should read pressure within a set of typical ranges, dependent on patient position and be (almost) identical to one another:
  - Supine: 5−20 cmH_2O
  - Sitting: 15−40 cmH_2O
  - Standing: 30−50 cmH_2O
- Detrusor pressure: The initial detrusor pressure should be zero, or as close to zero as possible, as the resting abdominal and intravesical pressures should be identical.
- ‘Live’ signals: The abdominal and intravesical pressure signals should be ‘live’, demonstrating minor variations in pressure with breathing or talking and the variations should be the same on both pressure recordings, with the detrusor pressure remaining unaffected.
- Cough checks: The patient should be asked to cough at every 1 minute of recording, or every 50 ml filled volume, to ensure that the abdominal and intravesical pressure signals are responding equally. Coughs should be performed before and immediately after voiding.

Additional urodynamic investigations

Videocystometry

Videocystometry is typically performed on patients presenting with complex disorders or those of neurological origin. The methodology is similar to conventional urodynamics however the bladder is filled with a radio-opaque dye as opposed to saline. X-ray fluoroscopic imaging is taken throughout the filling and voiding phases of the investigation. This enables the bladder anatomy to be visualized alongside concurrent pressure measurements. It is particularly useful for patients with neurogenic LUT dysfunction and in the diagnosis of diverticula, fistulae, vesicoureteric reflux, observation of bladder neck mobility such as in recurrent stress urinary incontinence, and urethral function during voiding. Videocystometry is expensive, arguably more invasive for patients, and most importantly patients are exposed to radiation, therefore the benefits of the test should be judged to be greater than the risks when requesting the investigation.

Ambulatory urodynamics

Ambulatory urodynamics is performed when conventional and/or video cystometry have failed to reproduce or explain patients’ symptoms. The test can additionally be used for patients with neurogenic LUT dysfunction. Ambulatory urodynamics utilizes physiological filling of the bladder while the patient is fully ambulant and can, therefore, reflect physiological bladder behaviour while they carry out their usual daily activities. Intravesical and abdominal pressure are measured, as with conventional cystometry, over an extended period of time. A urine-loss pad can be worn by the patient to facilitate recording urinary leakage. The pad encompasses a small current throughout a grid network of wires. As urine conducts electricity, the current can be short circuited and the resistance to electrical conductivity can be measured. Therefore, the occurrence of leakage and, to somewhat, the degree of leakage can be recorded. Asking the patient to cough regularly throughout the test is essential to retrospectively check signal quality.

Urethral pressure measurement

The urethral pressure can be defined as “the fluid pressure needed to just open a closed urethra” and its measurement is used to assess urethral closure and voiding function. The ICS published a standardization report of urethral pressure measurement in 2002. The clinical utility of urethral pressure measurements remains unclear and are not performed in all units.

Measurement of urethral pressure may be indicated in women prior to surgery for recurrent stress urinary incontinence, with suspected urethral relaxation incontinence, and with bothersome voiding symptoms and/or idiopathic urinary retention. Specific parameters should be noted when performing urethral pressure measurements, including patient position, bladder volume, and the type and size of the catheter.

Urethral pressure profilometry (UPP)

UPP is a measurement of the intraluminal pressure along the whole length of the urethra. The maximum urethral pressure (MUP) is defined as the maximum pressure of the measured profile, and the maximum urethral closure pressure (MUCP) is defined as the maximum difference between the urethral pressure and the intravesical pressure. Some studies have demonstrated that women with a low pre-operative MUCP (less than 20−30 cmH_2O) are associated with poor surgical outcomes for stress incontinence, particularly with retropubic procedures such as Burch colposuspension. This has not been demonstrated in patients who have undergone tension-free vaginal tape (TVT) and trans-obturator vaginal tape (TOT). There are many factors that lack standardization during UPP which negatively affects the clinical utility to direct surgical management and prediction of surgical outcomes.

Troubleshooting

Troubleshooting refers to the methods used to correct artefacts which are affecting pressure measurements and may lead to misinterpretation of the test findings. The clinician performing urodynamic investigations should be able to recognize and correct artefacts or errors at the beginning of the test and be able to perform continuous quality monitoring throughout the test. The ICS guidelines on good urodynamic practices outline common artefacts. Common artefacts and errors can occur due to:

- The presence of air-bubbles in fluid-filled catheters. These require flushing to eradicate the air-bubbles and to allow normal pressure transmission to resume (Figure 6a).
- Abnormal pressure readings of abdominal pressure. If the abdominal catheter has been placed in the rectum, then rectal contractions may be visualized as phasic increases in abdominal pressure. In patients with poor anal sphincter pressure, the catheter may slip into the anal canal and cause an artefactual rise in P_{det} due to a gradual fall in P_{abd}.

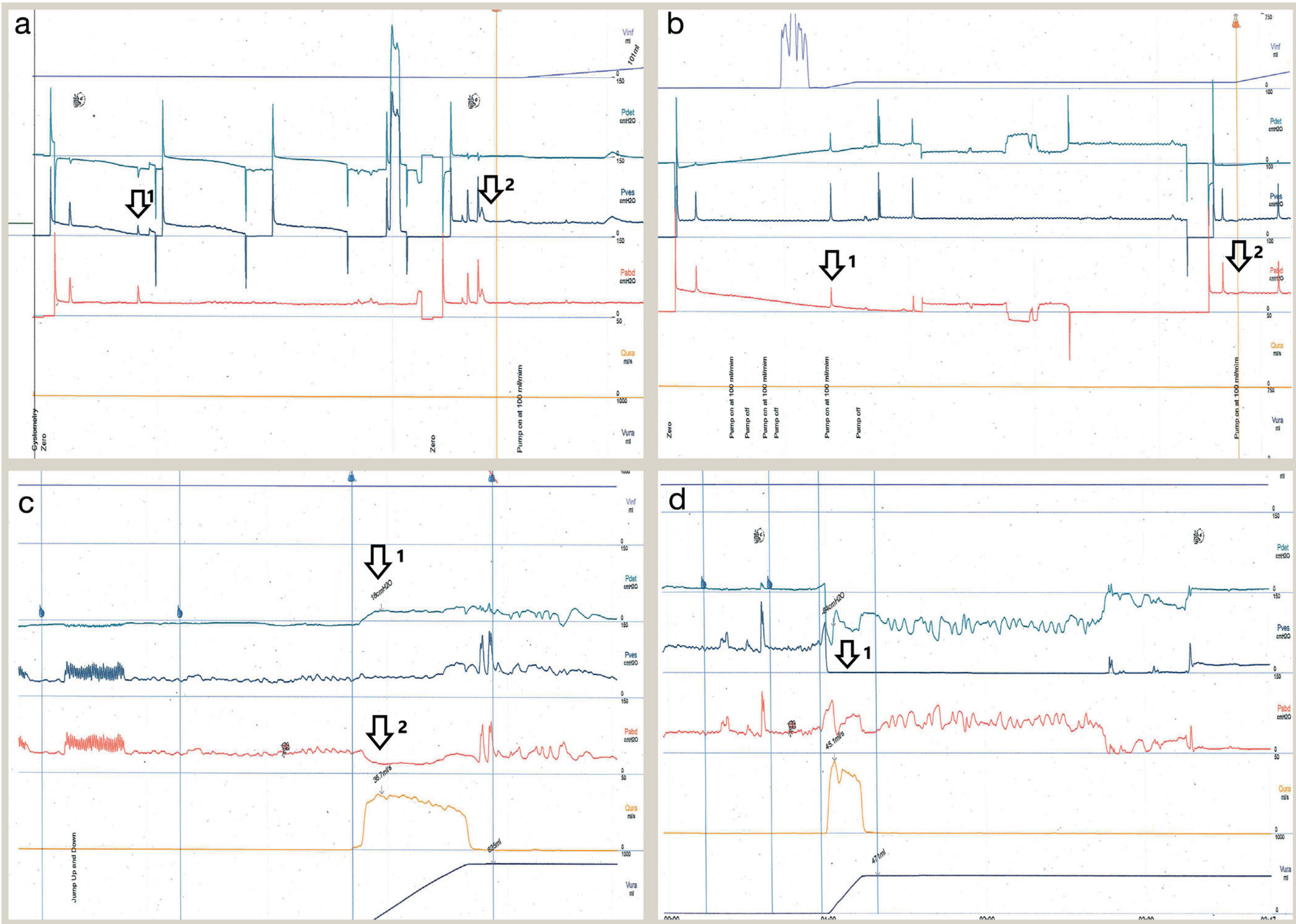

Figure 6 (**a**) Conventional cystometry study demonstrating pressure drift in the vesical line. Arrow 1 depicts the pressure decreasing in the vesical line which causes a subsequent negative detrusor pressure. If using a fluid-filled system, the vesical line should be flushed with fluid to eliminate the possibility of air-bubbles. All connections should be check for air-leaks in the system. Arrow 2 depicts correction of the artefact and normalization of the pressure reading in the vesical line which reflects the pressure reading from the abdominal line. On cough, there is a small biphasic pressure reading observed in detrusor pressure which is normal, and the detrusor pressure is reading 0 cmH_2O. (b) Conventional cystometry study using air-charged catheters demonstrating a pressure drift in the abdominal line. Arrow 1 shows the pressure measured from the vagina (abdominal pressure) decreasing with time. This can be due to displacement of the catheter e.g., the catheter is slipping out, or there may be an air leak in the system. Notably, when the patient is asked to cough the pressure from the abdominal line is reduced in comparison to the intravesical pressure and this is reflected in the detrusor pressure by large spikes. The system was checked for air leaks (e.g., tightening the connections between the catheters and the transducers) and the catheter re-zeroed to atmosphere and charged to the patient. Arrow 2 shows the abdominal pressure measuring the same as the vesical pressure, and the detrusor pressure is now stable around 0 cmH_2O. (c) Conventional cystometry study showing an artefactual increase in P_{det} (Arrow 1) during the voiding phase caused by pelvic, and abdominal, relaxation (Arrow 2). The decrease in abdominal pressure from baseline should be subtracted from P_{det} to obtain a true $P_{det}Q_{max}$. (d) Conventional cystometry study showing extrusion of the intravesical catheter during the voiding phase (Arrow 1). The $P_{det}Q_{max}$ cannot be calculated as it is simply registering the pressure measured by the abdominal catheter only.

The catheter placement should be assessed and repositioned if necessary.

- Leaks in the system which will dampen pressure transmission. The connections between the catheters, tubing, and transducer should be checked (Figure 6b).
- Pelvic, and abdominal, muscle relaxation during voiding: This can cause an artefactual increase in P_{det} and must be manually corrected by subtracting the decrease in abdominal pressure (during relaxation) from the detrusor pressure to obtain a true detrusor pressure at a maximum flow rate (Figure 6c).

Occasionally the vesical or abdominal catheter may be extruded during the voiding phase. The detrusor pressure at maximum flow rate cannot be ascertained in these circumstances (Figure 6d). The catheter can be re-inserted, the bladder re-filled, and the patient may attempt a second void.

The urodynamics report

The analysis of a urodynamic investigation should be carried out by the individual performing the test, immediately after the test has concluded. This allows the technical quality and clinical

Cystometrogram Report

SYMPTOMS: SUI when weightlifting, coughing, sneezing. Urinary leakage from sitting to standing, urgency with urge urinary incontinence. Nocturia (2x/night). Para 2 - uncomplicated NVD. Bladder diary received today.
URODYNAMIC QUESTION: To investigate the symptoms of mixed urinary incontinence.

MEDICATION: No bladder medications

ON EXAMINATION: unremarkable

CATHETER USED: 7 Fr TDOC air-charged

INITIAL FREE FLOW:
Voided volume (ml): 50mls - insufficient volume for analysis
Residual urine (ml): 0mls on bladder scan
Urine dipstick: 1+ blood - have sent for urinalysis - this is the first time the patient is aware that haematuria has been detected. Will contact GP to request a repeat urine sample in two weeks time.

FILLING PHASE:
Patient position: **lying**
Filling rate (ml/min): 100ml/min
Volume infused (ml): 420mls
Detrusor overactivity incontinence.
Resting p.det (cmH2O): -4
End filling p.det (cmH2O): 8
Vinf at first sensation: 135mls
Vinf at normal desire: 168mls
Vinf at strong desire: 275mls
Vinf at urgency: 406mls

PROVOCATION:
Urodynamic stress incontinence - large leaks on coughing
No stress provoked detrusor overactivity.

VOIDING PHASE:
Patient position: **Sitting**
PdetQmax (cmH2O): 19cmH20
Q.max (ml/s): 63ml/s
Volume (ml): 410mls
Voided by: majority detrusor **contraction**
Residual (ml): 10mls - large volume was lost through leaking

DIAGNOSIS: DO incontinence. USI with large leaks. Normal capacity bladder however bladder sensations appear to be early. Patient voids by detrusor contraction mainly with a good flow rate and to completion. Summary - DO incontinence and USI.

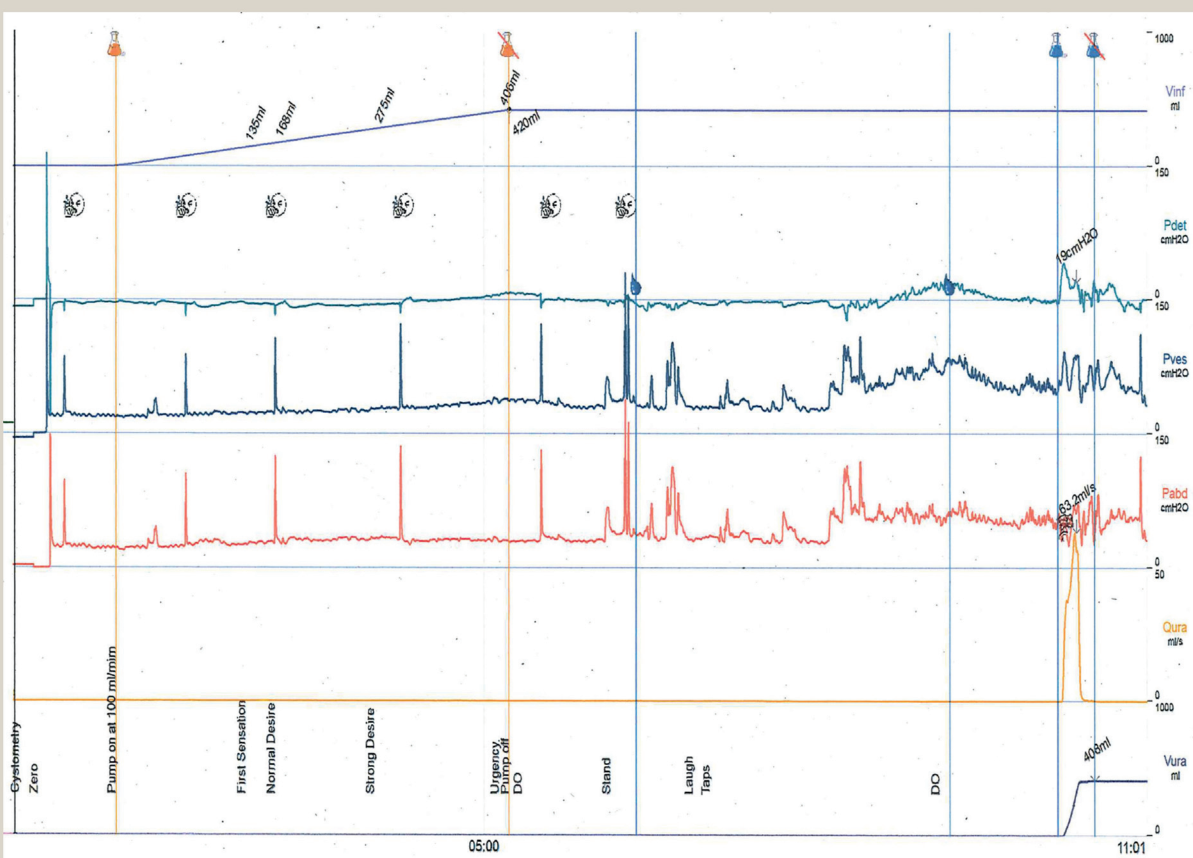

Figure 7 A standardized conventional urodynamics study and report adhering to ICS guidelines. The report depicts the patients' symptoms and outlines the urodynamic question. The report follows a standardized template that, in short, covers the interpretation and findings of uroflowmetry, and the filling, provocation, and voiding phases of conventional cystometry. Note, the report concludes with a concise conventional cystometry diagnosis.

reliability of the investigation to be documented. Contemporaneous changes made during the test i.e., corrections of artefacts or changes in catheter positioning and/or the filling rate, will only be known by the individual performing the test, therefore it is imperative this person reports the findings.

The quality of the investigation is paramount in being able to accurately answer the 'urodynamic question'. ICS guidelines state that an "ICS standard urodynamic (time based) graph" and an "ICS standard pressure-flow plot" are required elements of a standard urodynamics report. The bladder storage function (filling phase) should be described according to bladder sensation, detrusor activity, bladder compliance, and bladder capacity. The urethral closure mechanism during storage may be competent or incompetent. Voiding is described in terms of detrusor and urethral function and assessed by measuring urine flow rate and voiding pressures simultaneously. A standardized urodynamics report (Figure 7) should be departmentally developed and, as a guide, should include the following:

- Patients' symptoms and the 'urodynamic question'
- Medication history
- Uroflowmetry results, including the representativeness of the void as reported by the patient
- Catheters: type and introduction of i.e., obstruction during insertion
- Filling phase: patient position, filling rate, bladder sensation, detrusor activity, bladder compliance, and bladder capacity
- Accessory tests or measurements i.e., provocation techniques and urethral pressure measurements
- Voiding phase: patient position, total voided volume, detrusor activity (specifically, detrusor pressure at maximum flow rate), and residual volumes (if applicable)
- Conclusion and diagnosis (i.e., has the 'urodynamic question' been answered)

Conclusion

Urodynamics are an essential part of the investigation of LUT symptoms in women when conservative measures have failed. A detailed history, examination, and urinalysis is vital before performing urodynamics. The ICS sets out clear standards for urodynamic investigations and these recommendations should be adhered to by all institutions, and clinicians, performing the investigations. ◆

FURTHER READING

Abrams P, Cardozo L, Fall M, et al. The standardisation of terminology of lower urinary tract function: report from the standardisation subcommittee of the International Continence Society. *Neurourol Urodyn* 2002; **21:** 167–78.

Gammie A, Clarkson B, Constantinou C, et al. International Continence Society guidelines on urodynamic equipment performance. *Neurourol Urodyn* 2014; **33:** 370–9.

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Rosier PFWM, Schaefer W, Lose G, et al. International Continence Society good urodynamic practices and terms 2016: urodynamics, uroflowmetry, cystometry, and pressure-flow study. *Neurourol Urodyn* 2016; **36:** 1243–60.

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Practice points

- Urodynamic investigations are extremely useful for investigating symptoms of LUT dysfunction
- A comprehensive clinical history, examination, urine dipstick, and formulation of the 'urodynamic question' should be completed before undertaking conventional urodynamics
- ICS standards and guidelines should be adhered to when performing conventional urodynamics, and in relation to equipment set-up and calibration

