Basic understanding of urodynamics

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Abstract

Urodynamic investigations can provide an explanation for lower urinary tract symptoms, such as incontinence. A careful history and examination should be performed prior to urodynamic testing. Some urodynamic investigations are non-invasive, such as flow studies, while the majority used in the diagnosis of urinary symptoms are invasive, involving urethral catheterisation and placement of an abdominal pressure catheter. Bladder and abdominal pressures are measured during filling and voiding. Urodynamic equipment calculates detrusor pressure by subtracting abdominal from bladder pressure (pves − pabd = pdet). Urodynamics should be performed in accordance with standards published by the International Continence Society. Terminology used for lower urinary tract symptoms should also comply with International Continence Society standards. There is little morbidity associated with urodynamics, apart from a low risk of urinary tract infection and occasional discomfort. However as they are invasive, all clinicians referring patients for urodynamics should appreciate their use and application for clinical management.

Keywords comprehension; cystometry; urodynamics

Introduction

Urodynamics is the term that encompasses a number of tests used in the investigation of women with lower urinary tract symptoms (LUTS). Some are non-invasive, such as flow studies, but the majority are invasive, requiring urethral catheterisation and placement of an abdominal pressure catheter in the vagina, rectum or stoma. Urodynamic investigations should not be performed blindly, but should be carried out to inform management and answer a specific question. This is termed the "urodynamic question". Particular tests are used to answer specific urodynamic questions. For example, flow studies are performed if the patient is complaining solely of voiding dysfunction, whereas cystometry, filling and voiding, is performed if the symptoms are those of incontinence. Prior to attending for urodynamic testing patients should be given an information leaflet about what to expect during testing and any questions should be answered.

The International Continence Society (ICS) sets definitions and standards for urodynamic investigation. It publishes standardisation reports that are available online and should be adhered to. Non-invasive urodynamic tests, such as uroflowmetry, do not have any associated morbidity. Invasive tests, involving urethral catheterisation, have a recognised risk of urinary tract infections of between one and 10 %. Most centres do not advocate the prophylactic use of antibiotics for cystometry apart from in specific indications, for example renal transplant patients.

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Background

Before embarking on urodynamic investigation, the urodynamic question should be identified, i.e. what are the symptoms that require diagnosis. The type of urodynamic investigation required to provide a diagnosis will be determined by the urodynamic question. For the majority of women attending gynaecology clinics the question will be one concerning storage symptoms, such as incontinence or urinary urgency, hence filling and voiding cystometry will be the appropriate test.

Urodynamic question

The urodynamic question is formulated from a careful history, examination and completion of a frequency/volume chart (for at least three days). It is also vital that urine dipstick is performed before urodynamics to exclude urinary tract infections and diseases, such as bladder cancer, which can present with LUTS.

A urodynamic history should include information concerning urinary symptoms, their duration and their effect on quality of life. The degree of incontinence, its provocation and the number of pads used should be noted, as should any coexisting voiding difficulties. Relevant past medical history, including surgery, and neurological diseases should be included, as well as parity and obstetric history. The patient's drug history should be taken prior to urodynamic investigation as some medication, for example, diuretics can affect urinary symptoms such as frequency. The frequency/volume chart will contain information about voiding frequency, as well as voided volumes. On its own it can be used as a diagnostic tool, e.g. to differentiate between nocturnal frequency and nocturnal polyuria.

Urodynamic investigations

Urodynamic investigations include:

Non-invasive

Uroflowmetry (with or without measurement of residual urine)

Flow studies are used to investigate voiding dysfunction. The two most common flowmeters use either a rotating disc or a weight transducer. The flowmeter measures the volume of urine voided and the flow rate (ml/s). Flow pattern is recorded and is an important diagnostic tool, with patterns suggestive of obstruction, detrusor underactivity and straining.

The normal female maximum flow rate should be more than 15 ml/s with a "bell shaped" curve and no residual urine, measured by ultrasound scanning after voiding (Figure 1). Ideally more than one flow should be performed to diagnose voiding dysfunction, as the initial flow can be affected by anxiety about voiding into a flowmeter.

Also ideally the voided should be of reasonable volume, similar to the voided volumes recorded on their bladder diaries.

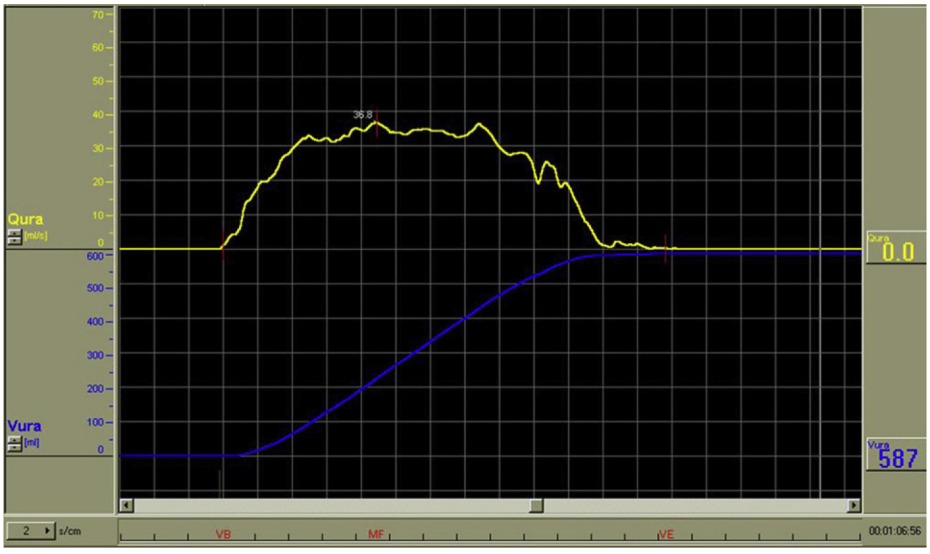

Figure 1 This uroflowmetry trace shows a normal flow curve.

Invasive

Standard cystometry (filling and voiding)

Filling cystometry: Filling cystometry involves the placement of a urethral catheter with either an internal or external pressure transducer. Bladder pressure (pves) is recorded while the bladder is filled naturally or by means of a pump. Normal saline is usually used as the filling medium. An abdominal catheter is used to record abdominal pressure synchronously; this can be placed rectally, vaginally or in a stoma. Urodynamic equipment records vesical and abdominal pressure (pabd) and calculates the detrusor pressure (pdet) from these (pves − pabd = pdet).

Voiding cystometry: Uroflowmetry provides information about voiding patterns and flow rates; however, additional information concerning voiding pressures is obtained with voiding cystometry. This additional information enables more accurate diagnosis of voiding dysfunction.

Filling and voiding cystometry – practical points

Equipment checks

Before the test commences various checks should be performed on the urodynamic equipment to ensure good quality control. The vesical and abdominal lines should have been zeroed to atmospheric pressure and, if external transducers are used, the external transducers should be at the ICS agreed reference level, the superior aspect of the symphysis pubis, during the test.

Urinalysis

This should be performed prior to cystometry, as coexisting urine infection could be exacerbated by catheterization and bladder function can be altered by infection.

At the start of cystometry

The patient is catheterized with either a double lumen catheter or two single lumen catheters. One line is for pressure measurement the other is for filling the bladder with fluid. The abdominal line can be placed rectally, vaginally or in a stoma. If a water filled system is used, the lines are flushed to remove any air bubbles that might be in the system. Pressure recordings of the abdominal and vesical lines should be within the ICS normal accepted range (see below). An initial cough check should be performed to check that the lines are recording accurately. When all of these checks have been performed the test can start.

Filling speed

There is no universally agreed filling speed, but a filling speed of 50 ml s/min is most commonly used. Faster filling rates can affect bladder function and slower rates may be required in someone with irritative symptoms or a neurogenic bladder.

Filling position

There is no ICS recommended filling position, but, in order to reproduce symptoms, filling is best performed in the upright position, sitting or standing.

During the test

During the test close monitoring of pressure and repetition of the cough test, once a minute, is necessary to ensure that quality is maintained during the test.

It may be helpful to annotate events during the test to aid interpretation, e.g. change in position.

The bladder capacity recorded during cystometry, cystometric capacity, should be similar to those on the frequency/volume chart, i.e. normal for the patient. Filling is stopped when the patient feels their bladder is full. During filling there should be a dialogue with the patient, so that bladder sensation can be noted with cystometric measurements. The volume at which the first desire to micturate (FDM) and strong desire to micturate (SDM) are felt should be noted. Additional symptoms, such as urgency, should be recorded along with any provocation that caused them. To reproduce symptoms various provocative manoeuvres should be performed, including running taps to provoke urgency, and coughing, while sitting and standing, to demonstrate incontinence. For patients whose incontinence is caused by exercise, short exercise regimes, including star jumps, can be performed in

addition. The cause of any observed incontinence should be recorded, for example detrusor overactivity incontinence or urodynamic stress incontinence. The degree of provocation needed to produce stress incontinence is worth noting to aid management, for example whether leakage occurred after the first cough or after a 5 min exercise regime. There is currently no agreed method to assess incontinence severity during urodynamics.

At the end of the test voiding cystometry is performed. If two single lumen catheters have been used during filling, 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 can be left in situ. Ideally double lumen catheters used in cystometry should be narrow,8 F or less, in order not to obstruct urine flow. A pressure/flow recording is made during voiding with particular attention to maximum flow rate as well as detrusor pressure at maximum flow (pdetQmax).

There is no ICS agreed nomogram for the assessment of obstructed voiding in women.

Any residual urine left after voiding is noted.

Interpretation

The test should be analysed in a systematic manner. Sensations experienced by the patient should be added to the interpretation.

Flows

The free flow is first noted. Flow pattern, maximum flow rate and the presence or absence of residual urine should be recorded. The patient should be asked whether the void was typical for them. There are published nomograms relating flow to voided volume and these are useful in interpreting flows.

Urethral pressure profiles

If urethral pressure profiles have been performed, these should be analysed, stating whether they are high, low or normal.

Cystometry

Filling: Ideally the clinician who interprets the trace should be present during the test. This is not always possible, but, at the very least the trace should have been carefully annotated with information concerning changes in position and bladder sensation. Individual lines, vesical, abdominal and detrusor should be marked on the trace, as line colours and their position on the trace can vary.

Quality control, checking that the lines respond well during the cough test and are within agreed limits, should be carried out before interpretation. Ideally any quality control issues will have been addressed during the test. The presence of any artefacts should be noted. The vesical line should be scrutinised carefully to see whether there has been any phasic activity, which would denote detrusor overactivity. If this is present then the number and height of these waves should be noted with any associated sensation or leakage. The presence of incontinence with the provocation that caused it will also inform the diagnosis.

The end filling pressure of the vesical line is noted and any rise in pressure is related to bladder capacity. This is termed compliance. A large rise in bladder pressure in relation to bladder capacity (>1 cmH_2O per 40 ml s) is termed low compliance. It would, however, be unusual to see low compliance in a woman without underlying neurological or intrinsic bladder disease.

Voiding: Flow pattern and maximum flow rate (Qmax) should be noted and compared with the initial flow. The patient should again be asked if voiding is typical for them. This is particularly relevant if there is a considerable difference between the free flow and the pressure/flow. Factors, such as bladder volume and patient anxiety, can affect voiding. The detrusor pressure at maximum flow (pdetQmax) is recorded and related to Qmax. Although there are no nomograms for use in women, it has been suggested that if Qmax is 10 mls/s or less the flow is low and if pdetQmax is 40 cmH_2O or more the flow is obstructed.

Having interpreted the test in a systematic manner, the urodynamic diagnosis can be made stating whether the patient's symptoms have been reproduced and whether voiding during the test was normal for the patient.

After the test

A report should be written that will be part numerical, e.g. pressures, flow rates, volumes etc and part descriptive. A description of the history, relevant examination and frequency/volume chart data should be included. Filling speed and the position of the patient during filling should be stated.

A typical report will include a description of filling and voiding phases with information concerning bladder sensation and the provocation that caused incontinence. It is important to state whether symptoms were reproduced and whether voiding was typical. The urodynamic diagnosis and management suggestions will conclude the report. Figure 2 shows a trace of a woman with urodynamic stress incontinence, while Figure 3 shows a trace showing detrusor overactivity.

Terminology

ICS has published definitions of urinary symptoms and urodynamic diagnoses. Two of the most relevant definitions are those of incontinence. Stress incontinence that has been proven during urodynamics is termed ***urodynamic stress incontinence*** (USI). The definition of this is "the involuntary leakage of urine during increased abdominal pressure, in the absence of a detrusor contraction". ***Detrusor overactivity*** is "a urodynamic observation characterised by involuntary detrusor contractions during the filling phase which may be spontaneous or provoked". ***Detrusor overactivity incontinence*** is "incontinence due to an involuntary detrusor contraction".

Quality control

Urodynamic investigations should be performed in a safe and scientific manner. Attention to sterile technique is an important aspect of this, while quality control ensures that test recordings are as accurate as possible. Regular calibration checks, see above, are part of this process and ensure that measurements are accurate. The ICS has published guidelines for good practice. Some of the most important aspects of this are listed below.

- Reference level: the reference height is the upper edge of the symphysis pubis. External transducers should be placed at this level.

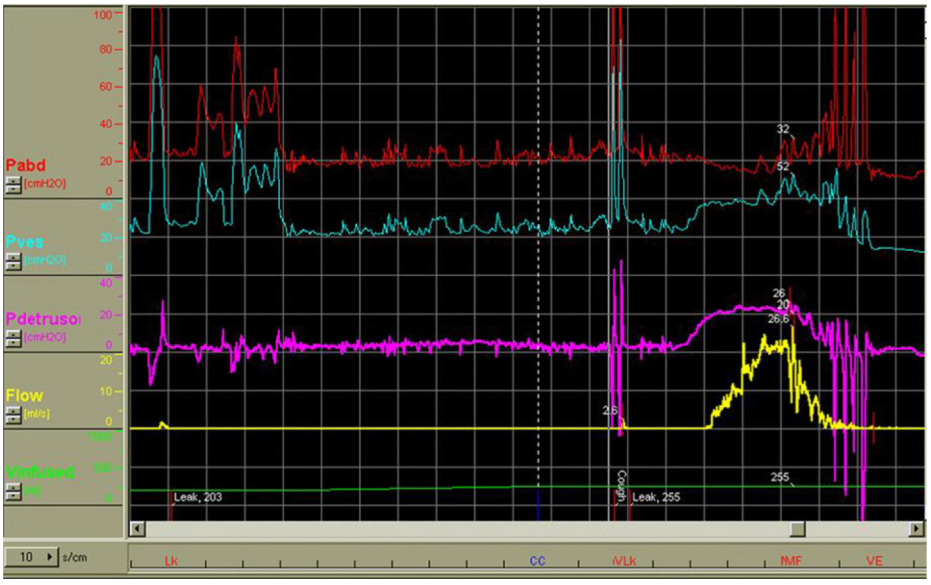

Figure 2 This filling and voiding cystometrogam shows urodynamic stress incontinence.

- Zero: zero pressure is the "surrounding atmospheric pressure". The vesical and abdominal lines should be zeroed to atmosphere before the test
- Resting values for abdominal and vesical lines: these should be 5–50 cm H_2O at the start of the test (lower values are expected with a patient lying, higher values with a patient standing). Body habitus also affects pressure values with higher readings for people with a higher BMI.
- Detrusor pressure: this should be near zero at the start of the test, as vesical and abdominal lines will have similar pressures when the bladder is empty.
- Live test: the test should appear 'live'; small fluctuations on the lines should be seen when the patient talks or takes a deep breath.
- Cough checks: the patient is asked to cough at regular intervals (about every minute) to check that the vesical and abdominal pressure signals response is the same.

Troubleshooting

This is the term used to describe methods that are used to correct any problems with measurements. Methods used include flushing fluid through lines to exclude air bubbles which can cause inaccurate pressure transmission. Troubleshooting should be carried out in a systematic manner to ensure that any recording problems are corrected before the test starts. If any errors occur during the test, such as falling abdominal pressure, the test can be paused while this is addressed. Figure 4 shows flushing to remove air bubbles in the water filled system.

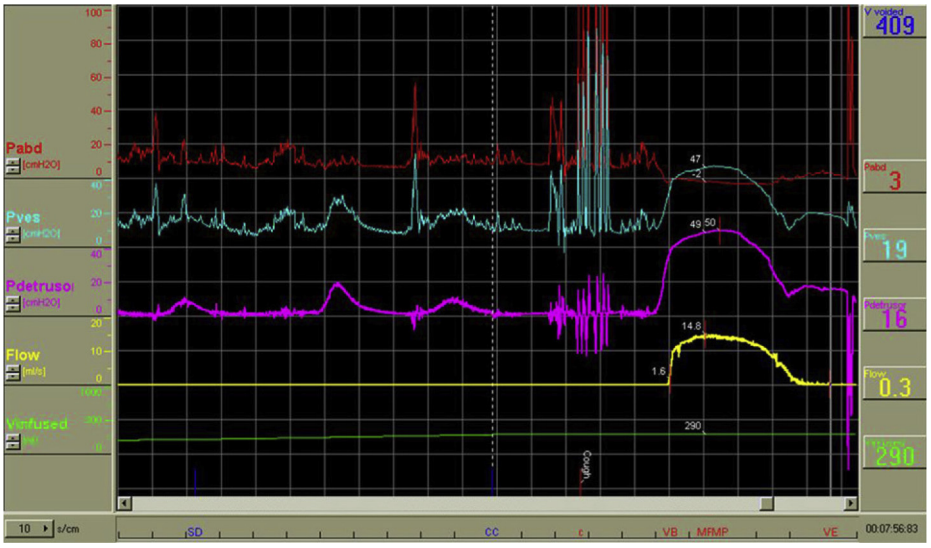

Figure 3 This filling and voiding cystometrogram shows detrusor overactivity.

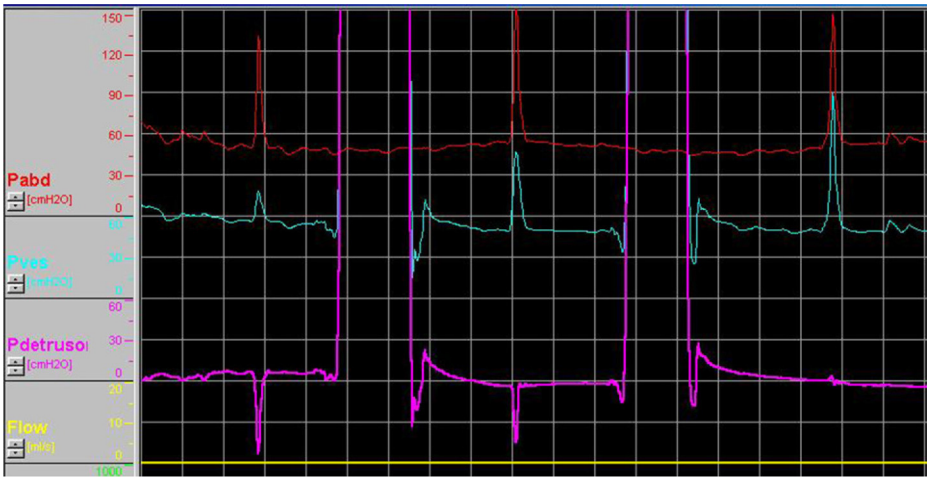

Figure 4 This filling cystometrogram shows flushing of water through the vesical line to correct poor pressure transmission.

Additional urodynamic investigations

Videocystometry

The methodology is similar to standard cystometry, but a radio-opaque contrast medium is used instead of saline for filling. Fluoroscopy is used at intervals during filling and voiding and anatomical information concerning bladder shape, vesicoureteric reflux, bladder neck mobility and urethral function during voiding is obtained. This is of particular benefit for patients with complex symptoms, for example those with neurological conditions or who have had surgery for stress incontinence. Although videocystometry can provide additional information, it is not without disadvantages. It is more expensive due to the cost of imaging equipment and contrast medium and exposes the patient to radiation. If videocystometry is performed then IR (ME)R, ionising radiation and medical exposure guidelines, should be adhered to and a clear department protocol of clinical indications for its use should be in place.

Ambulatory monitoring

Ambulatory monitoring involves the measurement of bladder and abdominal pressure using natural filling, recording two or three filling cycles. The patient wears a lightweight recording device, which has been formatted using a computer. Ambulatory monitoring is used solely as a second line investigation where standard or videourodynamics have failed to provide an explanation of symptoms. There are a number of controversial issues around ambulatory monitoring and, in terms of good practice; it should only performed at tertiary centres.

Urethral function studies

There are different techniques for measuring urethral function. Urethral pressure profilometry and leak point pressure measurement are the commonest ones in current use. They can provide additional information to inform the management of women with complex incontinence or who have had failed surgery for stress incontinence, but their use is controversial.

Urethral pressure profilometry

This is usually static and involves the measurement of urethral pressure while fluid is perfused slowly at a constant rate while the catheter is withdrawn. This measures the occlusive pressure of the urethral walls. The ICS defines maximum urethral pressure (mup) as the maximum pressure of the measured profile and maximum urethral closure pressure (mucp) as the difference between maximum urethral pressure and vesical pressure.

There is some evidence that a low preoperative mucp (<20 cm H_2O), measured by static urethral pressure profilometry, is related to poor outcome of surgery for stress incontinence using colposuspension. The literature is less clear on this relationship with TVT or TOT.

Leak point pressure measurement

This involves measurement of vesical pressure at which leakage occurs when a valsalva manoeuvre is performed with the bladder filled to a stated volume (valsalva leak point pressure). The pressure at which leakage occurs is recorded and the site of measurement (pves or pabd) is stated. If no leakage is seen when the bladder has been filled to a smaller volume, filling is continued and the test repeated, e.g. at 200 ml s and 300 ml s volume infused. The bladder volume at which leakage occurs should be stated.

Neurophysiological studies

These normally involve needle EMG recording to give an accurate measurement of electrical activity around the urethral sphincter. Neurophysiological studies are not performed routinely as part of urodynamic investigation, but have a role to play in the investigation of women with complex voiding dysfunction, so called “Fowler’s syndrome”. Their use should be confined to specialist centres.

Setting up equipment

Urodynamic equipment

Uroflowmeters, which measure flow rate and voided volume, have already been described. These can be freestanding and used solely for flow testing, for example in a flows clinic.

Urodynamic equipment used in filling and voiding cystometry will incorporate a flowmeter, as well as the ability to convert pressure signals from internal or external pressure transducers to an electric signal. Pressure transducers can be externally sited, as with water filled systems, or internal, i.e. when catheter tip

transducers or air charged catheters are used. Currently the ICS recommends the use of water filled systems for urodynamics, as there is uncertainty about the actual pressure measurements obtained using air charged catheters.

External transducers

Water filled system

These require either two single lumen vesical catheters, one for filling, usually 8F, and one for pressure measurement of a narrower gauge. Double lumen catheters are in common use. These are normally 6 – 8F. Water filled systems do have the disadvantage of registering movement artefacts. Attention must be paid to ensure that air bubbles are removed prior to cystometry, as their presence can cause damping of pressure signals. This is achieved by flushing the lines with sterile water from the syringes placed above or below the domes.

Dome covers

Vesical and abdominal pressures are transmitted to the external transducers, initially through the pressure catheters and then manometer tubing to the dome covers. These are placed over the transducers and are filled with sterile water. Three way taps are positioned to allow flushing of water across the dome covers and into the patient to prime the system and then to remove air bubbles during the test if necessary. The use of three way taps allows the tap to be opened to atmosphere to zero equipment at the start of the test and to check that the equipment readings have not drifted during the test. The vesical and abdominal lines should record zero when opened to atmosphere at anytime during the test.

Internal sensors

Catheter tip sensors

If this method is used, a disposable filling catheter is necessary in addition to the vesical catheter used for pressure measurement. These pressure measurement catheters have transducers mounted on their tip; these can be single, double or multiple. Abdominal catheters used in this method are similar to vesical catheters, but have one transducer and a firm plastic sleeve for ease of insertion. Most catheters of this type are not disposable and require sterilisation.

Air filled catheters

These catheters are disposable and are connected to a transducer that allows zeroing after catheterization and then priming of the small balloon that registers pressure. An air charged vesical catheter can have two lumina for filling and pressure measurement. Abdominal catheters are similar to vesical ones, but have only a single lumen and contain a stiffening wire to aid placement.

It is important to remember that pressures measured with external and internal sensors are not interchangeable and care should be taken when comparing results.

Equipment calibration

Calibration of urodynamic equipment should be checked regularly to ensure that pressures are being recorded accurately. This means checking that equipment is registering zero when the manometer tubing is held at the height of the external transducers and 100 cmH_2O when the tubing is raised 100 cm above the transducers. If calibration is inaccurate an engineer should be called to check the equipment, unless someone in the department feels confident to do this.

Conclusion

Urodynamics are an essential part of the investigation of LUTS in women when conservative measures have failed. A detailed history examination and urinalysis is vital prior to testing. It is important that clinicians are aware of what the test can involve and explain this to the patient prior to referral. ICS sets clear standards for urodynamic investigations and unit guidelines and practice should fall in line with these. ◆

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Practice Points

- Prior to undertaking urodynamics a careful history, examination and urine dipstick should be performed and the urodynamic question formulated
- Urodynamics should be performed interactively with the patient
- Urodynamicists should adhere to ICS standards and LUTS terminology