2 Imaging Modalities Used for Assessment of the Bladder

2.1 Plain Abdominal Radiograph

Prior to the introduction of ultrasound, the plain abdominal radiograph or the radiograph of the kidney, ureter, and bladder (KUB), followed by an intravenous urogram (IVU) or excretory urogram (EU), was the "workhorse" imaging modality of the urinary tract. The KUB also has a long history; one of the very first radiographic diagnoses made was a renal stone. Indeed, a book devoted to the contribution of radiography in the diagnosis and management of urinary tract calculi was published in 1908 by Harry Fenwick, a London-based surgeon.

However, the value of the KUB is now increasingly challenged by the explosion in the technical ability of the cross-sectional and computerized modalities such as ultrasound, computerized tomography, and magnetic resonance imaging, although it still maintains a role in certain situations. Its particular value is still in demonstrating the presence or absence of calcification or calculi related to the urogenital tract (Fig. 2.1).

For confident imaging, it is important to ensure the entire tract is imaged adequately from the upper poles of kidneys to the bladder base, and further supplementary views may be necessary. Oblique views, views in another phase of respiration, or in plain tomography can all contribute to improved visualization of the renal areas and increase diagnostic confidence. However, additional views, such as oblique views, do not contribute any further to the evaluation of suspected bladder calcification unless they are taken as part of a contrast-enhanced series. On lateral views, the bladder is overlain by the pubic bones.

The bones should be scrutinized for congenital vertebral anomalies; for example, widened pubis symphysis seen with bladder exstrophy and destructive bony lesions in adults of appropriate age group indicates malignant or infective bony disease, and a neural cause for bladder dysfunction (Fig. 2.2). The bladder outline itself is poorly seen, as there is often insufficient surrounding fat around the bladder to confer visibility by virtue of a density gradient, unlike the kidneys and their abundant surrounding retroperitoneal fat.

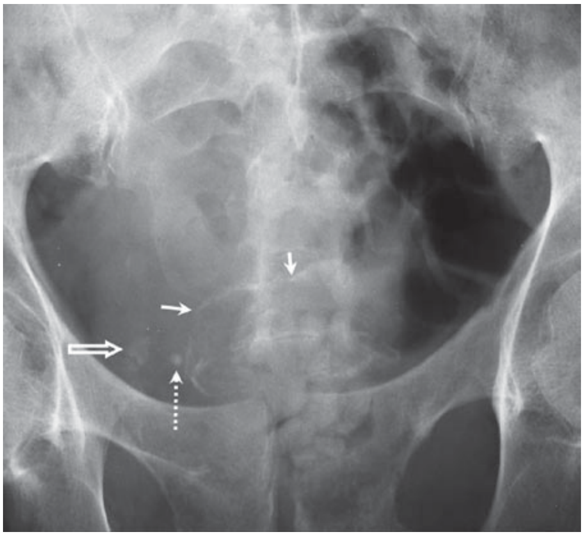

Fig. 2.1 A plain radiograph showing layers of calcification within the bladder (*short arrows*). This proved to be calcified bladder carcinoma. The plain radiograph has the highest sensitivity (after computerized tomography) for identification of calcification within the urinary tract. However, calcification should be differentiated from other causes of pelvic calcification, such as phleboliths (*hatched arrow*), ovarian or uterine calcification, and calcium in arteries or lymph nodes (*open arrow*)

2.2 Intravenous Urogram (IVU)

Intravenous (sometimes also called excretory) urography was first introduced into radiological practice in the early 1900s, although a retrograde pyelogram

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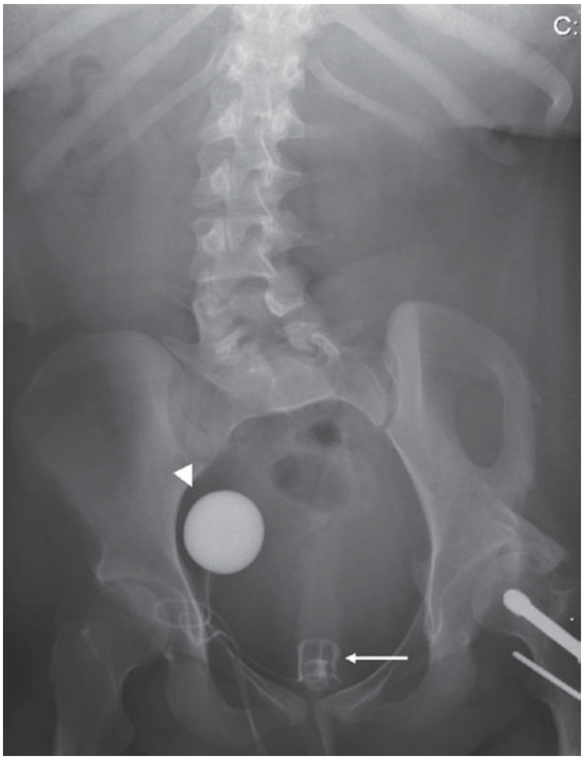


Fig. 2.2 A plain radiograph showing an artificial urethral sphincter (*arrowed*). Also note the contrast-filled balloon reservoir of the sphincter (*arrowhead*) located at the right of the pelvis

was first performed as early as 1906, very soon after Röentgen's discovery of the X-ray. The technique of intravenous urography has changed very little over the intervening years. Although it is principally a method for imaging upper tract anatomy, it also gives some indication of bladder anatomy and abnormality. The early images are dedicated to the study of the upper urinary tract, but later views will show gradual opacification of the bladder.

Unfortunately, full distension of the bladder takes time, and views are not as informative as those obtained by retrograde cystography. Nevertheless, there are many conditions that can potentially be seen on these "bladder" views, but the study suffers from having large "blind" areas. The anterior and posterior bladder walls are not seen; consequently, the false negative rate is appreciable. Comparative studies in patients presenting with macroscopic hematuria have shown accuracy rates of 26–80% for the diagnosis of bladder cancer, (Fig. 2.3a, b). Consequently, the use of the IVU for imaging of the lower urinary tract is now very limited. It is not indicated for routine bladder imaging.

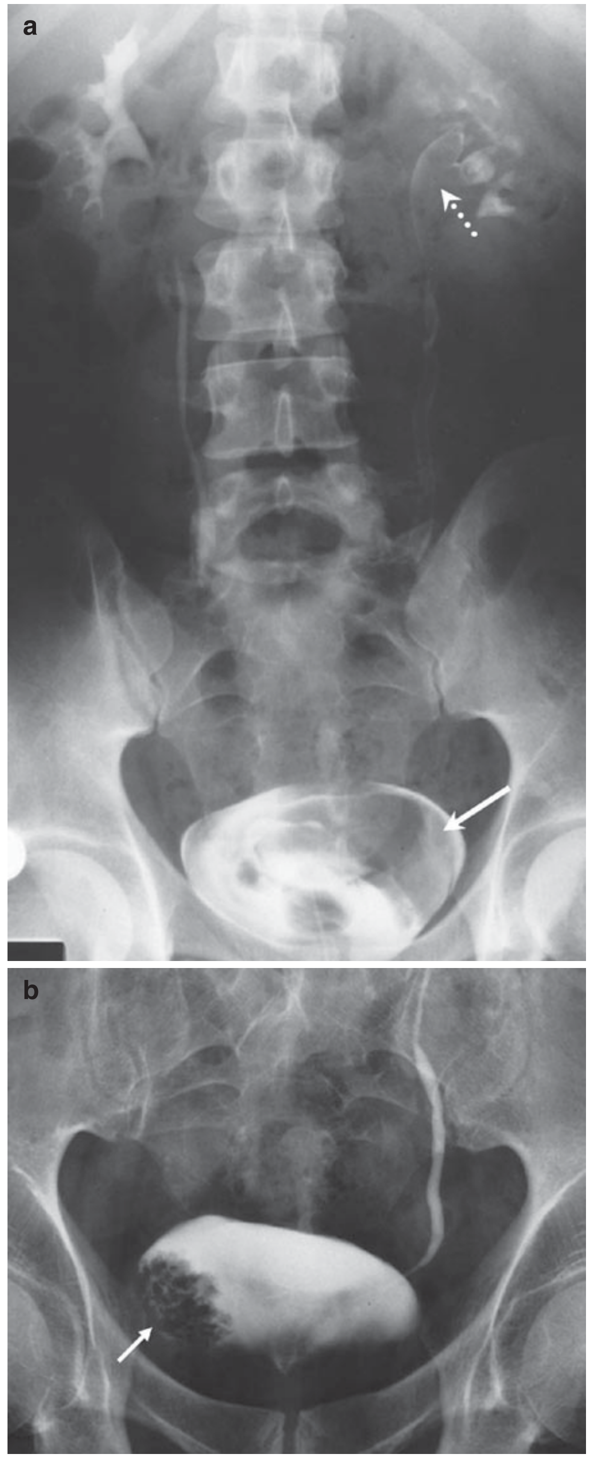


Fig. 2.3 (**a**) An intravenous urogram (IVU) taken in a patient with hematuria originating from the left kidney. A clot can be seen in the bladder (*arrow*), and also in the left ureter and renal pelvis (*hatched arrow*). A clot in the bladder is typically large and smooth in outline, and usually fills the bladder, but the appearances are otherwise nonspecific. (**b**) An IVU image of the bladder showing a right-sided filling defect (*arrow*), which proved to be a bladder tumor

2.3 Cystography

In comparison to the IVU, this equally ancient contrast-based study still retains a central role for evaluation of the lower urinary tract. Cystography is the fluoroscopic study of the well-distended bladder (Fig. 2.4a, b). It is an invasive study that requires instrumentation or catheterization of the urethra or bladder, using an aseptic technique. During this study, the bladder can be evaluated for any areas of thickening (such as trabeculation) or any structural abnormalities (such as a diverticulum). Intravesical or mural abnormalities are seen as filling defects within the pool of contrast, and stones (or foreign bodies) are recognized by their mobility. Reflux up the ureters, the consequence of either abnormal ureteral insertion, as seen with reflux nephropathy, or the result of widened, incompetent ureteral tunnels as a consequence of long-standing high pressure voiding or after ureteric reimplantation, can be recognized.

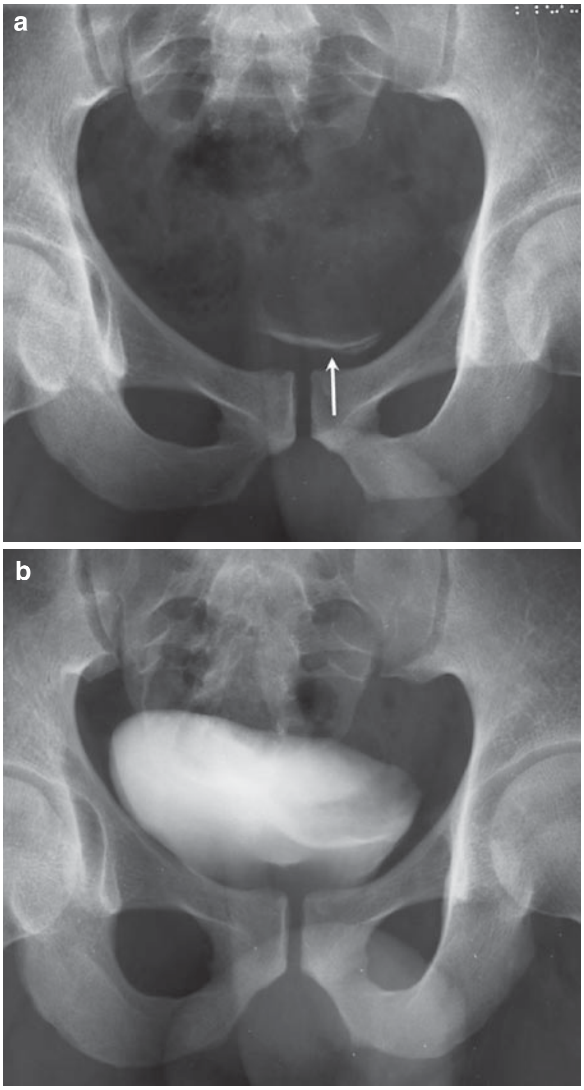


Fig. 2.4 A plain radiograph (**a**) and accompanying cystogram (**b**) in a patient with thin mural calcification (*arrow*) in a patient with schistosomiasis

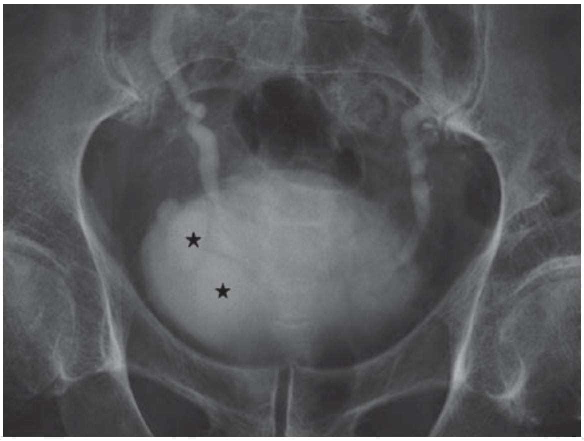


Fig. 2.5 A bladder view showing the poor resolution for the posterior wall. In this case, there are two posteriorly placed bladder diverticula (*starred*). Note that detailed analysis of the internal characteristics of these diverticula is impossible. Ultrasound, CT, or MRI do not have this limitation

The study has similar limitations to the IVU in its inability to visualize the whole bladder, particularly the posterior wall (Fig. 2.5). Oblique views are easily carried out with an interactive study such as cystography, but views are still limited, and this limits its value when compared to the cross-sectional modalities such as ultrasound or CT. Lateral views of the bladder are often non-diagnostic, as the pelvic bones degrade the image. Furthermore, there is no information about the surrounding structures, particularly tumors that may have invaded through the wall or any abnormality of the colon, such as diverticular disease and abscess that may have spread to involve the bladder.

In practice, there are two areas where contrast cystography is of continuing clinical value: the exclusion of bladder leak, either postoperative or traumatic (though CT is more accurate in this respect, although difficult to interpret at times) and the study of ureteral reflux (although this can also be studied with alternative, nonirradiating/less-irradiating modalities, such as ultrasound or nuclear medicine). A further advantage of the cystogram is that it can be combined with a micturating study to perform cystourethrography. This enhances the ability to identify ureteral reflux, as, in some cases, reflux is only seen during the higher intravesical pressures induced by the voiding reflex. Furthermore, evaluation during voiding provides a "global" view/analysis of the lower urinary tract; for example, the status of the bladder neck can be ascertained.

2.4 Ultrasound

2.4.1 Ultrasound of the Bladder: Technique

This is the commonest imaging technique used for the bladder, being simple to use, safe, and very patient-acceptable. A full bladder is essential, but the bladder should not be distended to the extent that the patient has pain. Only in a well-distended bladder can true wall abnormalities be recognized, otherwise apparent focal wall masses or diverticula can be simulated by invaginations of the deflated bladder wall, and conversely true bladder lesions, such as calculi, may be obscured by the non-distended bladder folds.

The supine position is adequate, but lateral scanning can help differentiate mobile intravesical abnormalities (such as stones or foreign bodies) from fixed lesions (such as tumors). A 3.5–5-MHz curved array probe is ideal, but the anterior bladder wall is sometimes better seen with higher frequency linear probes. During scanning, a systematic method should be used. First, the organ is scanned axially and note made of any asymmetry of the wall. The normal bladder wall is smooth and thin (the normal wall thickness is quoted as 3–5 mm, and measuring <3 mm when well distended). Next, the organ is scanned in the longitudinal plane. Asymmetry of the bladder wall is again assessed. In the midline, the bladder neck is seen as a short funnel. The lower ureters and the intramural ureteral tunnels should be particularly scrutinized, and both axial and transverse views are useful. Again, asymmetry is important, and stones lodged in the ureters can be suspected from prominence of the intramural portion of the ureters (Fig. 2.6a). Transrectal scanning can also be used to visualize the intramural ureters and ureteric orifices (Table 2.1).

2.5 Sonographic Appearances of the Normal Bladder

The normal bladder wall is smooth (Fig. 2.6a), and any focal variation in wall thickness should be scrutinized for mucosal-based masses or diverticula. The different layers of the bladder wall can occasionally be differentiated, but not sufficiently well for accurate analysis (such as for staging of bladder cancer). When well distended, the bladder is ovoid in shape in the longitudinal plane and quadrangular on axial scans. The bladder base (or trigone) is smooth in outline, and the intramural ureters are seen as linear corrugations along the base. These corrugations should not be mistaken for a mural mass. In the absence of prostatomegaly, the base should not be elevated and the bladder neck should be closed. Urine is fully transonic, but occasionally more concentrated urine may layer posteriorly or be seen as an echogenic jet as it ejects from the ureter. Differences in specific gravity may account for this visibility of what is theoretically transonic urine (as well as the visibility of urine "jets" expelled from the ureteral orifices as seen with color Doppler imaging (Fig. 2.6b, c).

The transonic urine makes bladder wall analysis easy, but marked reverberation artifact may be seen, and examination of the anterior wall (Fig. 2.6a), lateral wall, and base may be difficult. Suspected lesions of the anterior wall may be better evaluated with a higher frequency probe (7.5–10 MHz); the base may be better evaluated by transrectal scanning (Fig. 2.6d). Harmonic or pulse inversion imaging (generally, both methods remove low-frequency sonic artifact or "clutter," usually the result of reverberation artifact) help to better define the wall.

2.6 Color Doppler Ultrasound

On color flow Doppler imaging the normal bladder wall is avascular, but urine may be seen ejecting from the ureteric orifices as "color jets" (Fig. 2.6a, b). Visualization of jets is improved by hydration (500 mL of oral fluid intake prescanning, though some use intravenous hydration or diuretic agents to expedite urinary flow and bladder filling). Normal jets are well-defined, generally symmetrical cones of color turbulence, directed anteromedially. Jet frequency is 1–3/min depending on the state of hydration and level of diuresis, but symmetry is

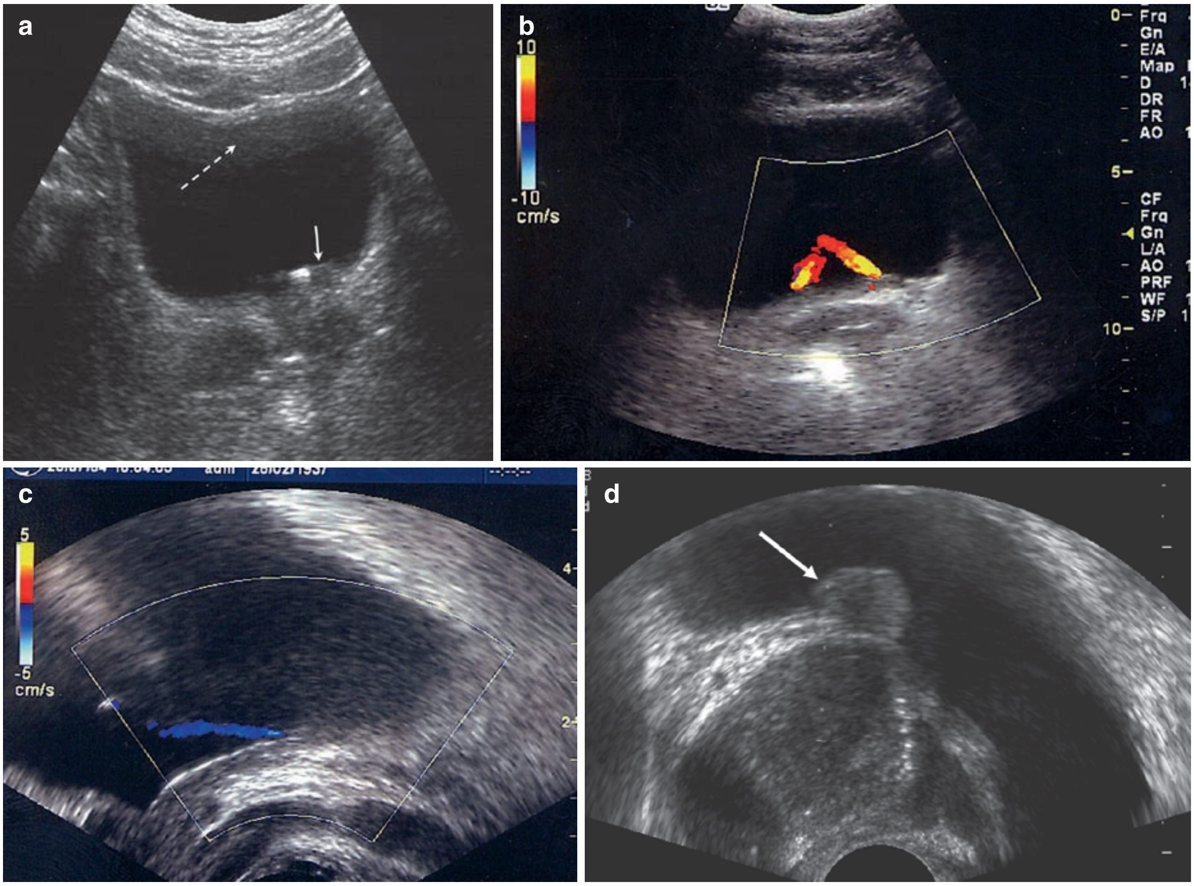


Fig. 2.6 (**a**) An axial ultrasound view showing a calculus lodged in the ureteric orifice. The surrounding tissue thickening is due to inflammatory change (*arrow*). Repeat scanning in a decubitus position would demonstrate lack of mobility, differentiating a stone in the lower ureter from one lying free within the bladder. Note also the reverberation artifact beneath the anterior bladder wall (*hatched arrow*), which interferes with analysis of the anterior bladder wall (see text). (**b**) An axial ultrasound view of the ureteral orifices and "ureteric" jets seen with color Doppler ultrasound. This represents urine flowing into the bladder. Normal frequency is 1–3 jets/min, depending on the degree of hydration and diuresis. However, the most important finding is symmetrical flow rather than the rate. Absent or slow flow from one side is seen in patients with complete or partial ureteric obstruction. (**c**) This is a more detailed view of the ureteric orifice and color Doppler ureteric jet. This image was taken using transrectal ultrasound. (**d**) Another transrectal ultrasound view demonstrating how certain basal lesions (*arrow*) are well demonstrated on transrectal ultrasound. In this case the mass proved to be a transitional cell carcinoma

a more useful assessment than jet frequency. Bilateral absent jets may merely reflect poor hydration.

2.7 Computed Tomography (CT)

The combination of ultrasound and contrast studies can pinpoint many of the clinical problems originating in the bladder. However, cross-sectional imaging in the form of CT and magnetic resonance imaging (MRI) are vital complementary tools in the investigation of several conditions, and indispensable for staging cancers. Their particular advantages are in providing detailed demonstration of overall bladder and pelvic anatomy (Fig. 2.7). CT, however, has limitations when applied to the urinary tract beyond the bladder. Imaging of the prostate, penis, and urethra are better evaluated with MRI. Nonetheless, recent advances such as multislice scanning with isotropic, or at least near isotropic imaging, have further improved the precision of CT.

Table 2.1 Ultrasound examination of the bladder

Preparation: Full bladder – at least 200 mL, and preferably >400 mL
Position: Supine (oblique/decubitus in some)
Probes: 3.5–5 MHz curved array probe. 7.5–10 MHz may be useful for the anterior wall (±Harmonic/Pulse Inversion imaging)
Method: Scan systematically in both axial and longitudinal planes
Images: Axial and longitudinal positions
Assess: Bladder wall Thickness – normally <3 (range 3–5 mm) mm thick when well distended Trabeculation Focal masses – assess location, whether solid/cystic, does it continue above bladder wall? Does the mass shadow? Is it mobile? (use decubitus scanning to decide)
Diverticula – location, size of diverticulum/opening, stone/mass inside diverticulum
Bladder base Ureteric orifices and intramural ureter– calculi, ureterocele, jets Bladder neck Base elevation – prostate enlargement
Scrutinize the blind areas (use Harmonic/Pulse Inversion imaging) Assess anterior wall using a 5–7.5 MHz probe Lateral walls – angulate the probe Bladder base – transrectal probe if suspicion persists
Bladder volume = Height × width × Depth × 0.52
Urinary flowmetry and postvoid residue (if appropriate)

Isotropic imaging means that the voxel (or block) of imaging is acquired as a perfect cube (*isotropic = identical in all directions)*, and is therefore as dimensionally accurate as possible. This means that three-dimensional reconstruction of the contrast-filled bladder is rendered precisely, and virtual cystoscopy is possible. These techniques are still being investigated; for example, CT urography (Fig. 2.8a–c) is being touted as one-stop imaging of the entire urinary tract, to replace ultrasound and conventional contrast studies, possibly even conventional cystoscopy, but this requires further technical developments. Enthusiasm for the new possibilities that these changes have brought to CT scanning must be tempered by the knowledge that there is an increase in radiation burden, and the kidneys are subjected to a large, potentially nephrotoxic contrast load in enhanced studies, which cannot be lightly dismissed.

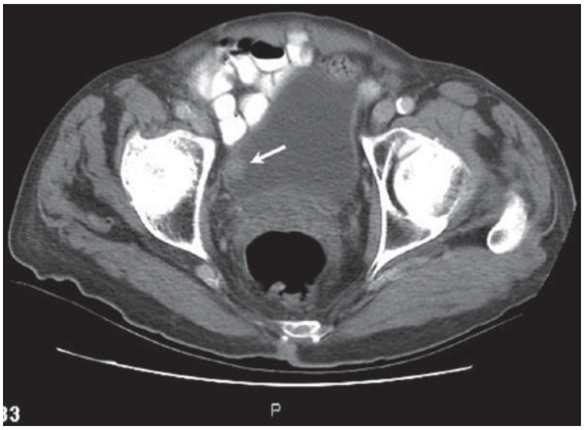


Fig. 2.7 An axial computerized tomographic view of the bladder. CT and MRI are best at demonstrating pelvic anatomy, and essential for tumor staging. A mural-based soft tissue mass is seen on the right lateral wall (*arrow*). This proved to be a stage T2b bladder cancer. Although CT and MRI can demonstrate a mass, biopsy is necessary to confirm its nature

Table 2.2 lists the technical details of CT of the bladder.

2.8 Magnetic Resonance Imaging

MRI of the pelvis provides much better anatomical visualization than CT, because of its inherently superior contrast resolution. In particular, heavy T2-weighted MRI is ideally suited for imaging of the urinary bladder, as the organ is filled with fluid (Fig. 2.9a, b). Relatively longer imaging times have proved problematic in MRI, but CT is not the only radiological technique to benefit from rapid technological changes. MR imaging is now faster with less movement artifact, and therefore improved image quality and resolution. Contrast-enhanced images can further improve bladder visualization. More recently, diffusion weighted MRI, where the MRI signals and imaging is weighted toward the diffusion characteristics of water, has been used to evaluate bladder cancer in particular. Its value still needs to be defined, but it is an example of the rapid changes taking place in MRI imaging of the bladder.

The obvious advantages of MRI include the lack of both ionizing radiation and nephrotoxic contrast media

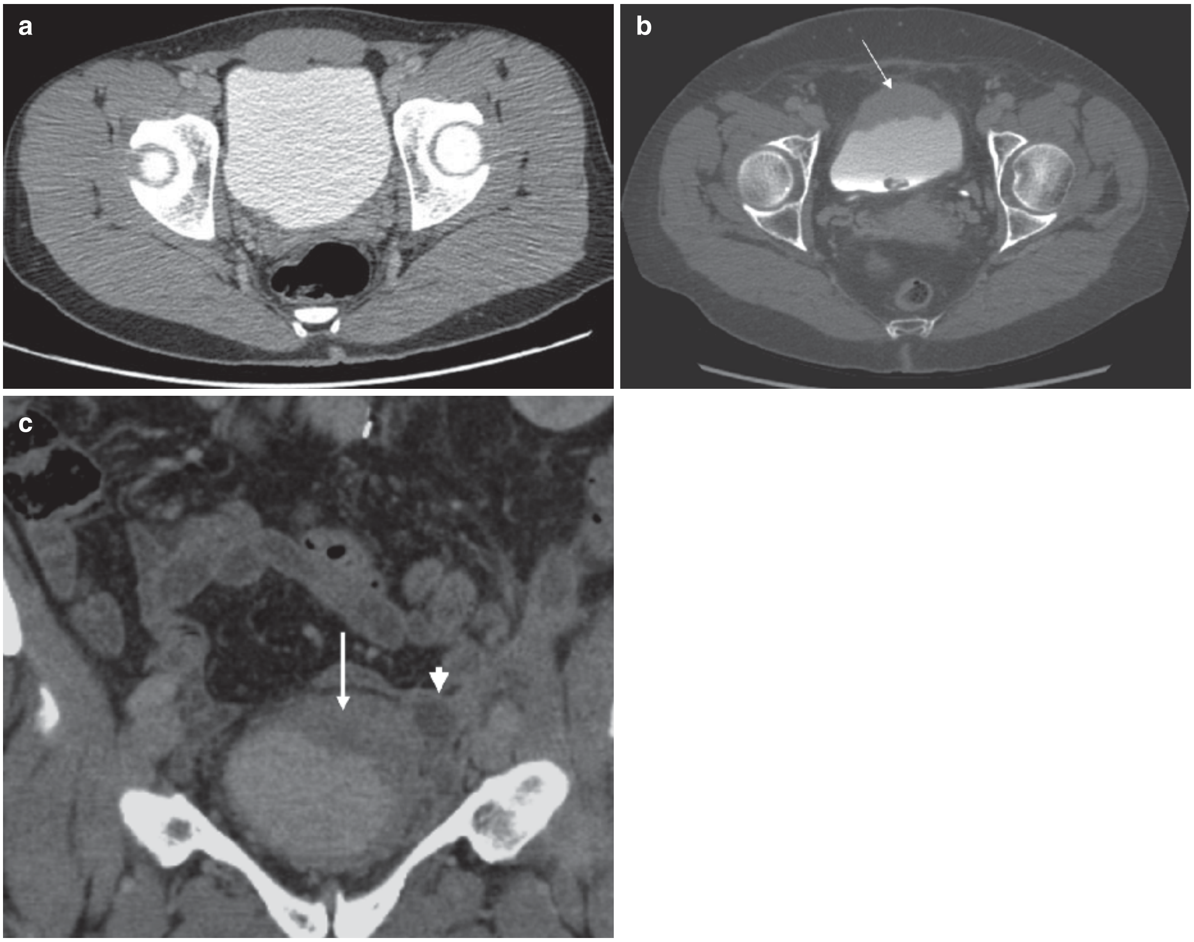


Fig. 2.8 (**a–c**) Three images taken from different patients who underwent CT urography for the evaluation of macroscopic hematuria. The first image shows a normal bladder (note the thin, smooth outline). The second image shows an anteriorly placed bladder wall thickening (*arrow*) that proved to be a bladder tumor. The last image is a coronal image showing a superiorly placed bladder tumor (*arrow*) with evidence of extravesical extension (*arrow head*). As these images demonstrate, CT urography is better than cystography or US for the global evaluation of the urinary tract for causes of hematuria

necessary for CT, which is particularly useful in pregnancy and renal failure. The indications for MRI have been slowly increasing over the past decade, and it is now used as the standard imaging modality for staging pelvic cancers. It is better than CT for the anatomical depiction of the bladder wall. Table 2.3 details the technical aspects of MRI of the bladder.

2.9 Lower Tract Urodynamics

The imaging modalities explained above are principally anatomical investigations, with little useful or direct information about the functional normality or otherwise of the bladder. The bladder is a storage organ that, once full, empties down a conduit, much as any inflated structure with an inherent elasticity to its wall and with a single outlet pipe with a regulatory valve would do. Such a structure should obey simple, well-known physical principles, and be analyzable according to these principles. Although this concept of the dynamic assessment of bladder filling and emptying has obvious attractions, such tests have their limitations in practice. These arise from the technical difficulties of accurate in-vivo measurement and the innate complexity of bladder function, which challenges the simple physical concepts outlined above. Finally, there is considerable overlap between the different clinical

Table 2.2 Computed tomography of the bladder

Preprocedure	Fasting for 4 h Full or moderately full bladder Intravenous access
Procedure	Oral Contrast medium for 30–60 min before, but this can be omitted for modern scanners CTKUB – this is a low-dose, unenhanced technique, best for visualizing urinary tract calculi Standard enhanced CT of abdomen and pelvis, best as a general diagnostic study and for staging bladder cancers 100 mL of intravenous iodinated contrast medium injected at 3–4 mL/s. Acquisition commenced at 60–90 s after start of intravenous injection 2.5–5 mm slice thickness acquisition of the entire abdomen and pelvis Further acquisition can be carried out 7–10 min to show an opacified bladder (e.g., after trauma) CT urography – similar to above, but studies done at 7 min after a dual injection of contrast (e.g., 50 mL given at 0 min and 70 mL at 6 min). This allows the entire urinary tract (kidneys, as well as the ureter and bladder) to be seen optimally enhanced 0.625–1.25 mm slice thickness acquisition of the entire abdomen and pelvis
Viewing	The images are viewed as reformatted images in the axial and coronal planes and as 3D volume reconstructions

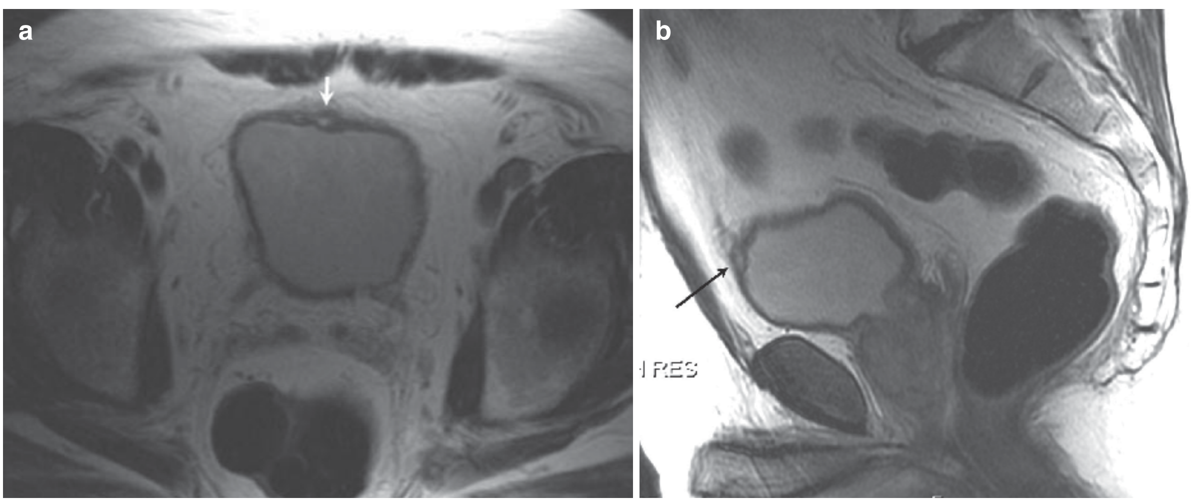


Fig. 2.9 Axial (**a**) and sagittal (**b**) T2-weighted magnetic resonance imaging views of the pelvis and bladder. MRI is particularly good at demonstration of the soft tissues, and on this T2 scan the urine in the bladder has a high signal. The bladder and the surrounding perivesical fat are well seen. An anterior urachal cyst or remnant is shown (*arrow*)

disorders of bladder dysfunction; for example, the storage function can be accompanied by disordered muscular stability, such that is sometimes impossible to separate the two and identify the dominant or primary cause.

A further and more prosaic difficulty is the lack of uniformity in the terminology used for the various indices of bladder function. As a result, it has proven difficult to compare published results and studies. Inevitably, many have regarded urodynamics as a difficult and imprecise study, with poor reproducibility and of limited clinical value. The work of the International Continence Society has improved this situation considerably, and it is hoped that terminological

Table 2.3 Magnetic resonance imaging of the bladder

Preprocedure	Full or moderately full bladder Intravenous access not routinely necessary
Procedure	Pelvic images are obtained with a pelvic coil T1 axial T2 axial T2 coronal Other sequences useful: Inversion recovery images Postcontrast T1 images 3D gradient echo images Sagittal images Diffusion weighted images

Note: This is merely an example of the images and sequences that may be used. The choice depends on the type and speed of the scanner used

Table 2.4 Terminology of urodynamic measurements

Pressure Intravesical – pressure within bladder Abdominal – pressure surrounding the bladder Detrusor – abdominal minus intravesical pressure
Filling rate Fast fill rate = 100 mL/min Medium fill rate = 50 mL/min Slow fill rate = 20 mL/min Physiological = body weight/4 in mL/min
Bladder sensation First sensation – when first aware of bladder filling First desire – can void, but can also wait Strong desire – persistent desire to void, no fear of leak Increased sensation – early first sensation or first desire Urgency – uncontrollable desire to void, fear of leakage
Detrusor function on filling Normal no substantial change in pressure on filling Detrusor overactivity – involuntary detrusor contraction, spontaneous or provoked. Phasic – wave-like, may not lead to leak Terminal – at full capacity, uncontrollable Neurogenic detrusor overactivity (previously hyperreflexia) Idiopathic detrusor overactivity (previously detrusor instability)
Voiding Maximum flow rate – during voiding Opening detrusor pressure – pressure on commencement of flow Pressure at maximum flow – lowest pressure at maximal flow rate Detrusor underactivity – detrusor contraction of reduced rate Acontractile detrusor – no discernable detrusor activity

uniformity will help to properly define the clinical place of modern urodynamics. In particular, it is hoped that research protocols will use a more uniform methodology, allowing comparison between studies. A more solid evidence base may eventually ensue. Table 2.4 summarizes these various definitions.

There are a variety of methods for the assessment of lower tract urodynamics (Table 2.5). The last four techniques are further explained below.

2.10 Simple Flowmetry

This is the simplest test of gross bladder function, and is a very useful first test in a patient presenting with voiding dysfunction. In many patients with lower urinary tract symptoms, this may be the only test necessary. The test requires a flowmeter, of which the commonest type has a disk that rotates at a constant rate. The impact of the urinary stream on the disk alters its inertia, and the change in force required to sustain a constant rotating speed is computed into the urinary flow rate. A continuous flow-time curve is produced, with a linear record of the flow rates at each given time point in the micturition cycle. Fig. 2.10 is an example of a normal flow curve.

Table 2.5 Methods for assessment of lower tract urodynamics

Daily patient completed volume/urinary frequency charts (3–7 days) Daytime and night-time urinary frequency Volume of each void
Pad assessment (worn either for 1 h during test conditions or for 24–48 h at home) Confirms and measures stress incontinence/leakage, during activities such as walking, standing up, walking up stairs, coughing, bending, etc Increase in weight of pad >1 g/1 h or >8 g/24 h is considered to confirm leakage
Simple flowmetry
Ultrasound cystodynamogram (USCD)
Urodynamics (simple cystometry/pressure – flow studies or videourodynamics)

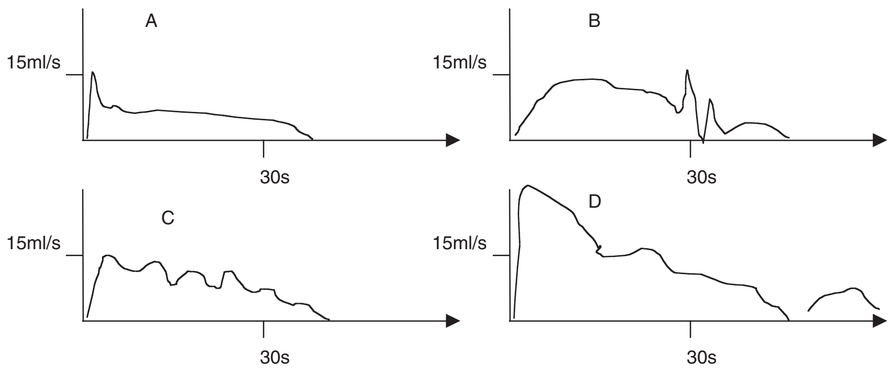
Fig. 2.10 A line drawing of a normal flow curve

After scanning the bladder is emptied into a flowmeter, and the following information calculated:

- Voided volume (should be > 150 ml)
- Maximum flow rate (should be > 15 ml/s)
- Average flow rate (should be > 10 ml/s)
- Flow pattern
- Post-void bladder residue (an empty bladder has < 25 ml)

(Note: Voiding parameters are affected by sex, age and the voided volume)

Artefacts:



Notes:
A = Initial artefactual spike due to a jet of urine hitting the spinning disc. True maximal flow rate will be lower than calculated by the flowmeter
B = Later artefactual spikes due to squeezing of the prepuce resulting in a ‘jet’ hitting the disc
C = Wavy profile due to abdominal straining
D = Prolonged flow inspite of normal flow rates. This is due to an overfull bladder and is often accompanied by further smaller voids

The age and sex of the patient will influence flow rates, but there are some recognized sources of measurement error. Of these, the amount of voided volume is most important, and a volume of >150 mL should be ensured. In practical terms this means that the patient should be asked to void when they feel their “normal” urge to void. Other sources of error are listed in Fig. 2.10 . In clinical practice it is often necessary to acquire a number of flow recordings on different days to account for artifacts due to straining and the like. Doing so helps to develop a unique reference range for a given patient.

2.11 Ultrasound Cystodynamogram (USCD)

This test is an extension of flowmetry, and further enhances the clinical value of flow rates for every day clinical management. By combining flowmetry with bladder ultrasound, additional information is obtained about bladder status and the completeness (or otherwise) of bladder emptying. Information about completeness of bladder emptying is important management information for patients with symptoms such as urinary frequency, *pis-en-deux* (feeling of

Table 2.6 The ultrasound cystodynamogram

Bladder ultrasound for anatomical information Good bladder distension is important (>200 mL at least) Bladder wall thickness. The normal wall thickness is quoted as 3–5 mm, and it measures <3 mm when well distended Bladder volume is measured by scanning in two dimensions. The formula used for calculating volume is 0.52 (height × width × depth) Prostate volume can also be estimated by scanning in two dimensions at right angles to each other, but it is not accurate Distal ureteric anatomy. In the presence of a significant postmicturition residue, the upper tracts may decompensate with hydroureter and hydronephrosis Intravesical abnormality, which may contribute to voiding dysfunction (e.g., diverticulum, bladder tumor, or calculus). The dimensions of the diverticulum should be measured
Functional information After scanning, urinary flowmetry is obtained and the postvoided bladder volume calculated using the same formula (an empty bladder has <25 mL, but for practical purposes a volume of <50ml 0 mL is considered clinically insignificant) The postvoid dimensions of any large diverticulum are also measured

incomplete emptying and the need to soon void again), frequent cystitis, and bladder outflow obstruction, among others. As with simple flowmetry, a meticulous technique is important. Table 2.6 lists the technical details of this test, with some examples of normal and abnormal findings.

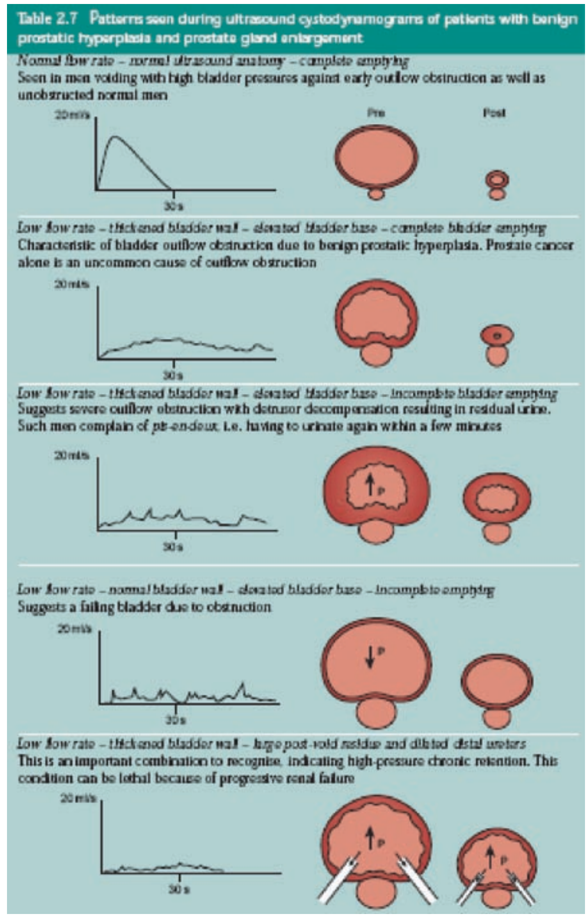


Table 2.7 Patterns seen during ultrasound cystodynamograms of patients with benign prostatic hyperplasia and prostate gland enlargement

Normal flow rate – normal ultrasound anatomy – complete emptying
Seen in men voiding with high bladder pressures against early outflow obstruction as well as unobstructed normal men

Low flow rate – thickened bladder wall – elevated bladder base – complete bladder emptying
Characteristic of bladder outflow obstruction due to benign prostatic hyperplasia. Prostate cancer alone is an uncommon cause of outflow obstruction

Low flow rate – thickened bladder wall – elevated bladder base – incomplete bladder emptying
Suggests severe outflow obstruction with detrusor decompensation resulting in residual urine. Such men complain of *pis-en-deux*, i.e. having to urinate again within a few minutes

Low flow rate – normal bladder wall – elevated bladder base – incomplete emptying
Suggests a failing bladder due to obstruction

Low flow rate – thickened bladder wall – large post-void residue and dilated distal ureters
This is an important combination to recognise, indicating high-pressure chronic retention. This condition can be lethal because of progressive renal failure

2.12 Urodynamics

The central limitation of simple flowmetry or the USCD is that there are no correlative data about bladder (or, accurately, detrusor) pressures. Low flow rates may be due to either outflow obstruction or weakness of the detrusor muscle and USCD may only provide indirect indication of these two entities (e.g., high pressure voiding, if chronic, will result in thickening of the bladder wall, while detrusor weakness may be associated with a thin bladder wall). Likewise, in a patient with urinary urgency, spasmodic high-pressure detrusor contractions may be the underlying cause. Neither flowmetry nor the USCD will identify this condition.

With urodynamics, continuous intravesical pressures and bladder volume are obtained during bladder filling; on voiding, continuous flow rates are obtained with simultaneous voiding pressures. Such dynamic measurements should provide a more complete assessment of voiding dysfunction, particularly if correlated with symptoms. This is simple cystometry or pressure-flow studies. If these studies are conjoined with intermittent fluoroscopy, then the functional abnormality can be further correlated with the lower urinary tract anatomy and structural abnormalities. This is videourodynamics or videocystometrography, and is the most complete functional assessment of the lower urinary tract.

Table 2.8 Videourodynamics: technique

Simple uroflowmetry is obtained before catherization, for the free flow rate
A 6–8F dual lumen catheter is introduced under sterile conditions into the bladder – one lumen is for measuring the bladder pressure and the other for filling the bladder
A rectal pressure catheter is inserted
The bladder is emptied manually and the residual volume measured
The catheters are connected to the urodynamics equipment and carefully flushed
The pressure catheters are normalized to atmospheric pressure at the level of the symphysis pubis, whether in the supine or erect position
Good subtraction from the pressure catheters is ensured. The patient is asked to cough. With good subtraction the detrusor pressure should show a short biphasic spike. If this is not obtained, the catheters should be reflushed and possibly may need to be resited. Care should be taken over this aspect
Filling should be at a "medium" fill rate of 50 mL/min unless neuropathic bladder is suspected, in which case a slow fill rate of 10–20 mL/min is used. Filling may be carried out in the supine, sitting, or erect positions
The volume and detrusor pressure at first sensation, first desire, normal desire, and strong desire is recorded. Volume at strong desire is the functional bladder capacity, but filling may be continued beyond this level, as the desire to micturate may abate when filling is stopped or the patient is brought to the erect position. Intermittent fluoroscopy is used, and note made of the bladder outline, ureteric reflux, whether bladder neck is open or closed, and any leakage
Any fluctuations of the detrusor line should be recorded, particularly if associated with urgency. This may be the only sign of detrusor overactivity
Once filling has stopped, the patient is brought to the erect position and the transducers adjusted to the level of the symphysis pubis. The detrusor pressure in the standing position is recorded
On fluoroscopy, the bladder neck is assessed. Normally the bladder neck should be at the level of the symphysis pubis or above. Descent beyond the level of the upper thirds of the symphysis and beyond signifies loss of pelvic support and urethral hypermobility ("pelvic floor or bladder neck descent")
During fluoroscopy, the patient is asked to cough and/or strain and any urinary leakage is noted. The abdominal pressure at leak is assessed (as the "abdominal leak pressure")
The patient is asked to void (a running tap in the background helps). The pressure at the commencement of voiding ("opening" detrusor pressure), pressure at maximal flow rate, maximal and average flow rates, and voided volume are recorded
Fluoroscopy during voiding is used to record the status and outline of the urethra

Notes
Good subtraction should be ensured by regular coughing during the filling phase and prior to voiding
Many women are unable to void when standing, and prefer the commode
As far as possible, privacy should be ensured
Some use prophylactic antibiotics
In those with a large postvoid residue, manual emptying should be considered at the end to reduce the chances of infection
Vaginal placement is as accurate as rectal catherization
In those with absent rectum, the pressure catheter may be placed in the stoma, but subtraction is difficult
Suprapubic bladder catherization may be used for bladder filling and pressure measurement

It is, however, an invasive test and should be used only in selected cases. Careful methodology is crucial, as the test is prone to technical faults. Attention to terminology is also important. The literature is replete with numerous descriptive terms for the various urodynamic abnormalities, a confusing situation that has only served to retard the wider application of this investigation. In this book, the recommendations of the International Continence Society (www.icsoffice.org) are used as far as possible. Table 2.8 lists the technical and procedural details of videourodynamics.

2.13 Normal Videourodynamics Study

In a normal study, there should be a residue of <50 mL on initial catherization, no substantial detrusor pressure rise on filling to a volume of 400–500 mL, and no leakage on provocation. On command, voiding should commence promptly, and be completed smoothly and rapidly. On fluoroscopy, the bladder outline should be smooth, without ureteric reflux, and the urethral profile should be normal. Table 2.9 is a list of all the normal values to be expected during urodynamics, further illustrated in Fig. 2.11.

Table 2.9 Normal urodynamic values and observations

On catherization No substantial pain Residue <50 mL
On filling First sensation at 150 mL First desire at >350 mL Strong desire at >450 mL No urgency or leak. Bladder neck closed
Detrusor pressure <15 cm H_2O during filling No contractions or detrusor pressure waves on filling or provocation (coughing) No substantial rise in erect position
Stress (coughing, valsalva maneuver) No leakage Bladder neck stays above pubis symphysis
Voiding Detrusor pressure stays 40–60 cm H_2O throughout voiding Maximal flow rate >15 mL/s Can interrupt flow The urethra milks back free of contrast Empties to completion (postvoid <50 mL)
Fluoroscopy Smooth bladder outline No diverticula No ureteric reflux On voiding, the urethra is smooth and widely open

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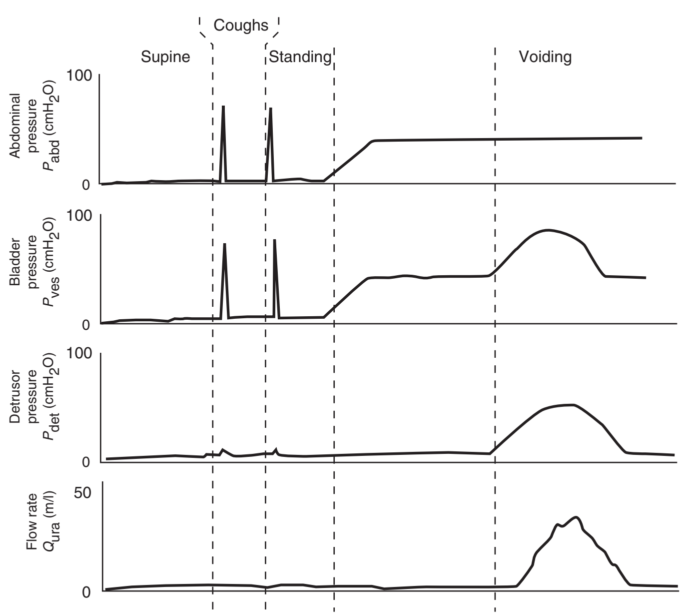

Fig. 2.11 An example of a normal urodynamic curve. The first curve is the abdominal (or rectal) pressure, the second the bladder pressure, and the third shows the corrected detrusor pressures. The final curve is the urine flow rate. Note that the detrusor pressure stays steady (and <15 cm H_2O) during the filling phase and does not change much on standing. Also that voiding commences promptly with a uniphasic detrusor contraction and a short flow curve. Refer to Table 2.10 for further normal values seen during urodynamic studies

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