Chapter 12

Ultrasound of the Bladder

Dr. med. Felix B. Trinkler
Ultrasound of the Bladder

Content

Topographical remarks ................................................................. 371
Bladder anatomy ................................................................. 371
Anatomical considerations ................................................................. 371
Bladder outlet obstruction ................................................................. 374
Transducers and patient position ................................................................. 373
Examination technique ........................................................................... 373
Diffuse bladder disease ........................................................................... 374
Detection and characterisation of diffuse bladder lesions ................................................................. 374
Bladder outlet obstruction ................................................................. 374
The bladder wall .............................................................................. 375
The bladder shape .............................................................................. 375
Bladder content ............................................................................... 376
Focal bladder disease ........................................................................ 380
Detection and characterisation of focal bladder lesions ................................................................. 380
Focal bladder wall lesions ................................................................ 380
Bladder stones ............................................................................... 388
Blood clot ...................................................................................... 389
Indwelling catheter (double-J-catheter, bladder catheter) ................................................................. 389
Ureterocele .................................................................................... 391
Air after cystoscopy or after catheterisation ................................................................. 392
Urine jet ...................................................................................... 392
Extravesical abnormalities ................................................................ 393
Pre-vesical ureter stone .................................................................. 393
Dilated hydroureter ........................................................................ 394
Lymphocele .................................................................................. 395
Aseites ...................................................................................... 396
Extravesical tumours ...................................................................... 396
Clinical importance of bladder ultrasound in clinical practice ................................................................. 397

Bladder anatomy

Anatomical considerations

The function of the bladder is urine storage and removal. A normal bladder capacity is approximately 500ml. The bladder is composed of contractile smooth muscle layers (detrusor vesicae), an outer adventitia, and lined by an inner mucosal layer (urothelium). The triangle between the two ureteral orifices and the urethral meatus at the bladder neck is called the trigone of the bladder. The vesical blood supply runs within the lateral and posterior bladder pedicles.

Echogenicity of the bladder and bladder content

When filled with urine the bladder content should be anechoic. Within the anechoic urine reverberation artefacts can often be seen (Figure 1 and 2).

Figure 1 Suprapubic abdominal ultrasound examination of the bladder. The bladder of this young male is partly filled with 257ml of clear urine. A healthy bladder content should appear anechoic.
On ultrasound the bladder wall appears as a three layer structure. The detrusor muscle is of medium homogeneous echogenicity. The outer serosa (adventita) layer and the inner mucosa (urothelial) layer are hyperechoic compared with the middle detrusor smooth muscle (muscularis propria) layer (Figure 3).

**Figure 2** Suprapubic transverse scan of the bladder in a young male. Dorsal to the bladder, the symmetric seminal vesicles can be seen. Behind the bladder roof hyperechoic reverberation echoes are often seen. This ultrasound artefact is produced by multiple reflections of an object if the acoustic impedances are too different (body to water). In this case the sound waves are reflected back into the bladder from the transducer-skin interface.

When filled, a normal bladder wall should have a plain appearance without any contour irregularity (Figure 4).

**Figure 3** The normal bladder wall is 3–5mm thick. The thickness of the bladder wall depends on how full it is. In a full bladder the thickness decreases to approximately 2–3mm.

**Figure 4** Healthy bladders have a plain appearance when filled. This image shows the cystoscopic aspect of the female bladder. We can see air bubbles on the roof and a plain normal looking mucosa.

**Examination technique**

**Transducers and patient position**

The easiest way to scan the urinary bladder is by an external suprapubic abdominal approach with a convex 2.5–5MHz probe. Most general practitioners will have such an abdominal probe in their standard equipment. The patient is examined in the supine position with a partially full bladder (200–300ml). If it is necessary to have more detailed information of the bladder roof, linear probes with higher frequencies (7.5–16MHz) can be used. The bladder floor, the distal and intramural part of the ureter can be visualised more accurately endosonographically in a lithotomy position with a higher frequency transrectal ultrasound (TRUS) in men, or with a vaginal probe in women (Figure 5 and 6). In the same way as other organs, the bladder should be carefully scanned in transverse and longitudinal sections. A transurethral approach into the bladder with high-frequency miniprobeS for bladder cancer staging purposes is not yet a standard procedure.

**Figure 5** Transrectal ultrasound of the bladder. Urine from the right ostium is seen just above the right seminal vesicle in a 34-year-old male.
The following structures are assessed in sonographic evaluation of BOO:

**The bladder wall**

Detrusor hypertrophy results in a thickening of the bladder wall and in augmentation of the bladder wall mass (BWM). Bladder wall thickness (BWT) can be directly measured with ultrasound by measuring the anterior bladder wall transabdominally with a 7.5MHz probe (or the posterior wall with a TRUS probe) on a defined bladder filling of 100–300 ml. Unobstructed normal BWT was found to be 3.0±1.1mm. A strong correlation between BOO and a BWT of greater than 5mm at 150ml filling was demonstrated (Figure 7). The problem with BWT measurement is that the BWT is volume dependent. There is no standard bladder volume for BWT measurement in a non-invasive setting. The use of catheterisation for BWT makes this an invasive diagnostic test. At present bladder filling volume for BWT measurement is not standardised (Figure 7 and 8).

Using BWT and bladder volume the BWM can be computed by multiplying the bladder volume by the wall thickness and the specific gravity of bladder tissue (0.957±0.026 g/ccm). There was a cut-off weight for an obstructed bladder of >50g. BWM of more than 80g suggests irreversible changes to the bladder detrusor muscle. However, the problem in BWM measurement is the interobserver and intraobserver variability and the fact that the bladder shape is never an absolute sphere in real life when using the bladder volume calculation. Uroflowmetry is an easy test to gain information about bladder voiding function, but it cannot discriminate between BOO and detrusor underactivity. Non-invasive BWT combined with BWM testing could provide the missing information about bladder contractility for the differential diagnosis between BOO and a “floppy” underactive bladder, in cases of low flow. The gold standard for the exact evaluation of the bladder contractility and BOO is still the invasive and expensive urodynamic pressure-flow study.

**Diffuse bladder disease**

The criteria to analyse diffuse bladder disease include sonographic evaluation of the bladder wall thickness, bladder shape and bladder content (echogenicity, capacity and post-void residual urine).

**Detection and characterisation of diffuse bladder lesions**

**Bladder outlet obstruction**

Bladder outlet obstruction (BOO) is the most common reason for diffuse morphological and physiological bladder changes. Subvesical obstruction has a very different aetiology. The most frequent reason in males is benign prostate hyperplasia (BPH). BOO leads to lower urinary tract symptoms (LUTS), infections and bladder stones owing to post-void residual urine. The interindividual different subjective estimations of the symptoms of LUTS can be documented with the international prostate symptom score (IPSS). In BOO, the detrusor smooth muscle compensates for increasing subvesical resistance with detrusor hypertrophy, which results in higher intravesical voiding pressure. The morphological expression of this compensatory up-regulation against subvesical resistance is an increase in muscle mass (muscle hypertrophy) and collagen deposition, which results in detrusor trabeculations and pseudodiverticula formation. In this early stage (BPH Stage 1) the high pressure results in clinical irritative voiding and symptoms, such as frequency and urgency until urge incontinence (known as overactive bladder symptoms (OAB)) owing to low bladder compliance with small capacity because of collagen deposition and overactivity. The collagen accumulation in high pressure voiding bladders may be a result of poor blood supply and poor oxygenation as a result of high intramural tension. Depending of the severity of the subvesical obstruction, the detrusor smooth muscle may decompensate (BPH Stage 2) by losing contractility, which results in a large capacity floppy bladder with high post-void residual urine volumes. Symptoms are nycturia, acute urinary retention or urinary overflow incontinence. Bladder compliance changes throughout the course of BOO and is not yet fully understood; however, it is important to be aware that most of the symptoms of BOO, such as urgency for example, are caused by autonomous adaptation of the detrusor muscle to subvesical obstruction.

Figure 7   Bladder wall thickness (BWT) 6.2–10.9mm in a male with benign prostate hyperplasia (BPH) Stage 2 with post-void residual urine of 60ml. BPH with a prostate volume of 70ccm and median lobe hyperplasia. Transrectal ultrasound biopsy could exclude the suspicion of malignancy because of elevated prostate specific antigen >4ng/ml. BWT of more than 5mm is suggestive of bladder outlet obstruction despite the measurement after voiding and without the standardised bladder filling of 150ml.
Ultrasound of the Bladder

Figure 8  Bladder wall thickness (BWT) measured on the anterior bladder wall with a linear probe 6.5 MHz in a male with benign prostate hyperplasia and bladder outlet obstruction.

The bladder shape

The bladder adaptation mechanism to compensate for chronic BOO is bladder muscle hyperplasia. The morphological changes are diffuse trabeculation of the detrusor muscle and formation of diffuse so-called pseudodiverticula. A primary congenital diverticulum of the bladder is a malformation of the bladder muscle layer with absent detrusor muscle and extravesical protrusion of the mucosa layer (Figure 9). They are often located behind the prostate on the bladder floor and are usually not associated with generalised bladder wall thickening. In contrast pseudodiverticula are a diffuse secondary bladder reaction in BOO. Pseudodiverticula are secondary acquired pulsion diverticula and often have a narrow neck (Figure 9−11).

Figure 9  Typical aspect of trabeculation of the detrusor muscle during cystoscopy in a patient with benign prostate hyperplasia and bladder outlet obstruction. The hypertrophy of the detrusor muscle results in a thickening of the bladder wall and formation of muscle trabeculation as morphological sign of high pressure voiding.

Bladder content

Bladder volume can be calculated by scanning the bladder transversely and longitudinally and using the following ellipsoid formula:

\[ \text{Volume} = \text{height} \times \text{width} \times \text{depth} \times 0.5236 \]

However, the bladder is never totally spherical, therefore volume calculations must allow for some measurement error (Figure 12−18). Ultrasound bladder volume measurement is clinically important in defining the post-void residual urine in patients with bladder voiding disorders, especially BOO. As already mentioned the BPH obstructive stage can be estimated non-invasively by IPSS, uroflowmetry and ultrasound post-void residual urine measurement.

The differential diagnosis of overflow incontinence is easily performed with bladder ultrasound by detection of an overdistended bladder.

Normal urine appears anechoic; in patients with chronic bladder infection the bladder content appears cloudy because of the reflection of leucocytes and proteins.
Figure 12 Measurement of post-void residual urine (153ml) with the ellipsoid formula \((69.9 \times 61.2 \times 68.3 \times 0.52 = 153\text{ml})\) in a 72-year-old male with benign prostate hyperplasia Stage 2. Note the bladder wall thickened with trabeculation.

Figure 13 Measurement of post-void residual urine in a young male. The normal bladder is empty after voiding (<1ml).

Figure 14 Overflow incontinence with an overdistended bladder. The residual urine measured by ultrasound was 1049ml; however, after catheterisation 1500ml was evacuated. Therefore, it should be noted that in high bladder volumes ultrasound volume calculation underestimates volume.

Figure 15 Acute urinary retention in a 55-year-old male with chronic prostate obstruction and over-distended detrusor muscle. A volume of 1800ml clear urine was collected by catheterisation.

Figure 16 Chronic bacterial bladder infection in a female patient with a post-void residual volume of 139ml. The urine appears cloudy as a result of chronic infection.

Figure 17 An 80-year-old male with a permanent transurethral catheter for bladder outlet obstruction therapy. The bladder content is cloudy because of chronic urinary tract infection.
Focal bladder disease

Detection and characterisation of focal bladder lesions

Approximately 95% of all focal bladder wall lesions represent transitional cell carcinomas (TCC). Most of these are found during examination of painless macroscopic haematuria or chronic microscopic haematuria. Large carcinomas are detected easily on ultrasound, but a primary condition for the detection is a filled bladder because TCCs hide in empty bladders and small TCCs (<5mm) in particular are rarely seen on ultrasound. Approximately 10% of TCCs diagnosed on ultrasound are false-positives owing to bladder wall trabeculation, a prominent interureteral crest, calculi, haematoma or focal cystitis. Colour Doppler ultrasound is not always helpful in differentiation between coagula and bladder tumours because colour Doppler signals in tumours are not often present like they are in haematoma. Contrast-enhanced ultrasound (CEUS) is more accurate in these cases. Therefore, bladder ultrasound is not recommended for the exclusion of TCC in haematuria. All sonographically suspicious focal bladder lesions should be examined with careful cystoscopy. Even virtual cystoscopy with CT is inadequate in the detection of TCC because flat tumours (carcinoma in situ, pTis) are not detected.

Focal bladder wall lesions

Bladder tumours (neoplasia)

Over 90% of all tumours of the bladder are TCC. The incidence increases with age and they are usually found in patients between 65 years and 70 years old. Tabacco smokers have a four-fold higher risk in developing a TCC. Rare entities include squamous cell carcinoma (1%), adenocarcinoma (<2%) and urachal carcinoma (0.07–0.7%). TCC has a multicentre origin and they are believed to result from a molecular misprogramme of the urothelium. TCC has a high recurrence rate at different times and different sites (multifocal). It is a systemic cancer disease with lymphatic spread; metastases form when TCC invades the bladder muscle layer (≥ cT2) (Figures 19-26).
Figure 25 Colour Doppler in bladder ultrasound in a female patient. If perfusion within the tumour can be detected then the diagnosis of this focal tumour on the bladder neck can be confirmed. Note the extended local bladder wall thickening.

Figure 26 Contrast-enhanced ultrasound (CEUS) has a better sensitivity in the detection of low blood flow within a suspicious focal bladder lesion and can reliably diagnose TCC. However, because cystoscopy and transurethral resection of the bladder tumour (TUR-B) is mandatory the use of CEUS in every suspicious bladder lesion is questionable because of cost.
Schistosomiasis

Schistosomiasis (also known as bilharziosis) is a parasitic infection caused by trematodes. It is an endemic disease in Africa (especially along the river Nile in Egypt), Asia, Middle East and South America. Schistosomiasis is transferred by freshwater snails who release cercariae to the water. The infection is then transmitted to humans who drink or swim in contaminated water. Cercariae may migrate through intact skin to the subcutaneous vessels. The adult worm then migrates by systemic circulation throughout the host’s body and releases eggs in different organs including the bladder, where they can be seen on cystoscopy. As a result of the high antigenic character of the eggs, granuloma and fibrosis are induced. Schistosoma haematobium is associated with an increased risk of bladder carcinoma. Therapy consists of an oral dose of the anthelminic, praziquantel.

Figure 29 View on cystoscopy of schistosomiasis lesions in the bladder mucosa of a patient from Africa.

Extravesicale bladder infiltration (pT4 prostate cancer)

Ultrasound alone cannot discriminate between primary bladder tumour (e.g. TCC) and tumours of other origin that infiltrate the bladder wall. The classic type is pT4 prostate cancer, which infiltrates the posterior bladder wall and often obstructs the distal ureter, resulting in hydronephrosis.

Figure 27 Cystoscopic aspect of a pT4 Gleason score 4+4=8 prostate carcinoma, which has infiltrated the bladder floor. The macroscopic aspect of a solid transitional cell carcinoma (TCC) G3 can look similar.

Pseudotumours

If ultrasound of the bladder is not done properly, prostate enlargement with middle lobe hyperplasia may mimic a focal TCC, especially in cases with gross haematuria. A prominent interureteral crest, bladder folds or bladder trabeculation, especially in not properly filled bladders, may also mimic TCC on ultrasound examination.

Figure 28 A 73-year-old patient with painless macrohaematuria. Suprapubic ultrasound is mimicking a large solitary spherical bladder tumour caused by a large median lobe of prostatic hypertrophy.

Figure 30 The same patient as Figure 29 presented with lower urinary tract symptoms (LUTS). On bladder ultrasound with a high-frequency linear probe a calcified schistosomiasis egg within the bladder mucosa of the anterior wall is easily detectable (yellow mark).
**Endometriosis of the bladder**

Endometriosis is caused by extraterine spread of endometrial cells. These cells stay under the influence of female hormones during the menstrual cycle and can be the cause of pelvic pain during menstruation. If the bladder is affected by endometriosis, urinary urgency, frequency and painful voiding that worsens during menstruation are typically seen.

*Figure 31 A young female with infertility, menstrual cycle dependent dysuria and urgency. Bladder ultrasound shows parauterine fluid accumulation with involvement of the bladder wall. A diagnosis of endometriosis of the bladder was proved on cystoscopy and histological transurethral bladder biopsy.*

**Diverticulum**

Primary bladder diverticula are not common (incidence of 1.7%) and are a congenital malformation. A bladder diverticulum is a herniation of bladder mucosa through the bladder wall. Large diverticula can act as paradox reservoir during bladder voiding. Post-void residual urine and urine stasis can result in chronic urinary tract infection, stone formation and malignant urothelial transformation (i.e. TCC). Therefore diverticula, especially in those with a narrow neck, should be carefully examined during cystoscopy.

*Figure 32 Solitary primary bladder diverticulum behind the enlarged prostate with middle lobe hyperplasia. Note the narrow neck of the diverticulum (4.4mm)*
Blood clot

As a complication following transurethral-bladder (TUR-B) or transurethral-prostate (TUR-P) surgery, post-operative bleeding may be present, especially if the patients are under platelet aggregation inhibitor therapy (e.g. aspirin). Heavier bleeding may result in a blood clot, bladder tamponade and painful acute urinary retention, which is a urological emergency. In this condition bladder ultrasound leads to a quick diagnosis and often provides the correct indication for re-intervention.

Figure 37 Bladder ultrasound presents a large coagulated haematoma in this patient post-operatively.

Indwelling catheter (double-J-catheter, bladder catheter)

Foreign bodies, bladder catheters and double-J ureter catheters can be easily located on bladder sonography. The correct location of a double-J-catheter (pigtail-catheter) inside the bladder and within the pyelon of the kidney can be demonstrated with ultrasound, which is important in, for example, pregnancy hydronephrosis, where radiography is contraindicated.

Figure 38 The sonographic appearance of a pigtail catheter is characterised by a typical hyper-echoic double contour of the ureter catheter. If there is some calcification on the catheter surface “stone shadowing” can be demonstrated.

Endovesical intraluminal content (filling defects or intravesical masses)

In addition to the investigations of the bladder wall and shape, ultrasound examination of the bladder content can provide good diagnostic information about bladder diseases.

Bladder stones

Bladder calculi are the secondary result of chronic lower urinary tract infections, usually due to incomplete voiding because of BOO or hypocontractible bladders. Ultrasound can demonstrate stones by a typical stone shadow behind the hyperechoic stone. Sometimes it is adequate to move the patient from standard supine position to a lateral position to identify mobile bladder stones.

Figure 35 Bladder calculus in male with bladder outlet obstruction. The twinkling artefact is not really seen because of the even surface of calcium phosphate stones. The proof of the calculus is the shadow casting behind the stone. Only minimal twinkling artefacts can be demonstrated because of the relatively plane surface of stones (also seen Figure 34).

Figure 36 Cystoscopy in the same patient as Figure 35. Two large round stones with a plane surface can be seen inside the bladder.
Ureteroceles are ureteral anomalies appearing as cystic dilatations of the terminal ureter. They are four times more frequent in females. Only 10% are bilateral. We can discriminate between orthotopic intravesical and ectopic ureteroceles, which do not drain to the bladder. The later often cause incontinence or poor bladder voiding. Stasis of urine in the obstructed system often causes chronic infection and leads to secondary stone formation. Ureter anomalies are often concomitant with kidney malformation. The Meyer-Weigert rule, which describes complete ureteral duplication, states that the lower kidney pole ureter orifice inside the bladder is more cranial and lateral compared with the more caudomedial ostium of the upper pole kidney system. The routine use of ultrasound in paediatric patients means that ureteroceles are diagnosed pre- or postnatally. One method of treatment for obstructed ureteroceles is transurethral incision.
**Urine jet**

Urine jet is the rhythmic expulsion of urine through the ureteral orifice (ostium) into the bladder. It can be visualised by realtime colour Doppler ultrasound of the bladder. The diagnostic role is to identify the bladder trigone and assess the ureteral function particularly for the diagnosis of ureteral obstruction. The absence of unilateral urine jet may suggest unilateral obstruction owing to urolithiasis. Urine jets are not only seen on colour Doppler, but on B-mode grey scale ultrasound if there is a difference in the specific gravity of ureteral and bladder urine.

**Air after cystoscopy or after catheterisation**

Air below the bladder roof is often a result of transurethral manipulation, catheterisation or cystoscopy.

**Extravesical abnormalities**

In bladder ultrasound, it is important to assess the area surrounding the bladder. It is therefore crucial to know how full the bladder is. In an empty bladder there is no information available on bladder pathology and there is a greater potential for misinterpretation of extravesical findings as bladder related pathologies.

**Pre-vesical ureter stone**

Sonography of a filled bladder allows the pre-vesical ureter to be inspected. In cases suspect of a pre-vesical ureterolithiasis including the typical symptoms of pollakisuria and flank pain, the patient should be advised to attend bladder ultrasound with a full bladder.
Lymphoceles

Lymphoceles can occur as a complication, for example after retropubic radical prostatectomy with lymphadenectomy. If the bladder is empty, a lymphocele can mimic post-void residual urine.

Figure 50 Post-operative lymphocele within the cavum of Retzius, ventral to the bladder. With an empty bladder a big lymphocele can often be misinterpreted as filled or non-empty bladder.

Dilated hydroureter

In ureterolithiasis, stones are often blocked at the level of the crossing with the iliac vessel or pre-vesical. Using colour Doppler the iliac vessels can easily be identified and a dilated hydroureter can be seen on ultrasound, if there is not too much gas in the colon.

Figure 49 Hydroureter over the iliac vessel crossing in a patient with blocking calculus within the distal ureter. Hydroureter on the right, Ureteric crossing of the iliac vessels.

Figure 51 Lymphocele around the iliac vessels in the region of the obturator triangle after pelvic lymphadenectomy in a prostate cancer case.
Ascites
As well as lymphocele, ascites in a case with an empty bladder can be misinterpreted as urine in pelvic bladder ultrasound.

Figure 51 Ascites in a patient with metastatic colon cancer disease. Above the bladder there is a fluid accumulation pushing the intestinum cranially.

Extravesical tumours
When interpreting pathological findings inside the bladder with bladder ultrasound it is crucial to know if the bladder is filled or empty. In the completely empty bladder, the bladder wall is often not detectable, which can lead to a misinterpretation of the pathological findings around the bladder as bladder diseases.

Figure 52 A female patient with history of haematuria. Suprapubic ultrasound was performed as the first-line diagnostic procedure and it suggested papillary bladder cancer (i.e. transitional cell carcinoma (TCC)). We were surprised to find no TCC inside the bladder on performing a cystoscopy.

Clinical importance of bladder ultrasound in clinical practice
Ultrasound of the bladder is very important in routine patient evaluation in the urological clinic. It is the easiest way to evaluate bladder voiding in a non-invasive way by measurement of the post-void residual urine transabdominally. If bladder ultrasound is performed carefully, it can provide detailed information of different diseases of the bladder in a non-invasive way and without the disadvantages associated with radiographs.