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Ultrasound of the urinary bladder

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Topographical remarks

The urinary bladder is part of the lower urinary tract and is located intra-abdominally sheltered within the bony pelvis. Traumatic bladder lesions are found mostly in polytrauma patients with associated pelvic fractures. The bladder is anchored to the anterior abdominal wall by the obliterated urachus. The bladder neck is fixed by the pelvic fascia. Against the pelvic side walls, it is cushioned by perivesical fat within the retropubic Retzius' space. The pelvic floor muscles, located caudally to the bladder, are important for urinary continence, especially in females. Only a part of the bladder is located retroperitoneally. The bladder dome sits next to the abdominal cavity; this is an important fact for the clinician to be aware of in order to avoid iatrogenic perforation during transurethral resection of the urinary bladder (TUR-B) or by insertion of suprapubic cystostomy tubes. In males, the bladder base is next to the prostate, the seminal vesicles, the ampullae of vas deferens and the rectum. In females, the posterior bladder wall is next to the vagina, the uterus and the adnexa.

Bladder anatomy

Anatomical considerations

The function of the bladder is urine storage and micturition. A normal bladder capacity is approximately 500 ml. The bladder is composed of contractile smooth muscle layers (detrusor vesicae muscle), an outer adventitia and lined by an inner mucosal layer (urothelium). The triangle between the two ureteric 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 [Figures 1 and 2].

Figure 1 **Suprapubic abdominal ultrasound examination of the bladder. The bladder of this young male is partially filled with 257 ml of clear urine. Healthy bladder content should appear anechoic.**

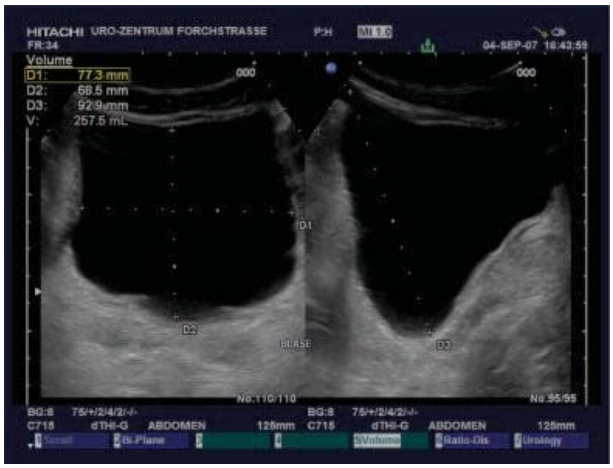
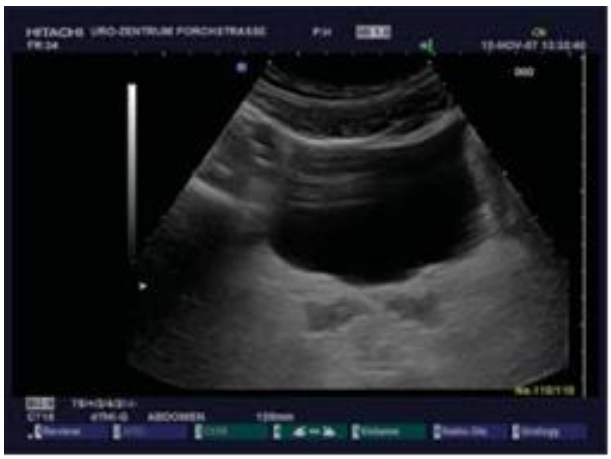


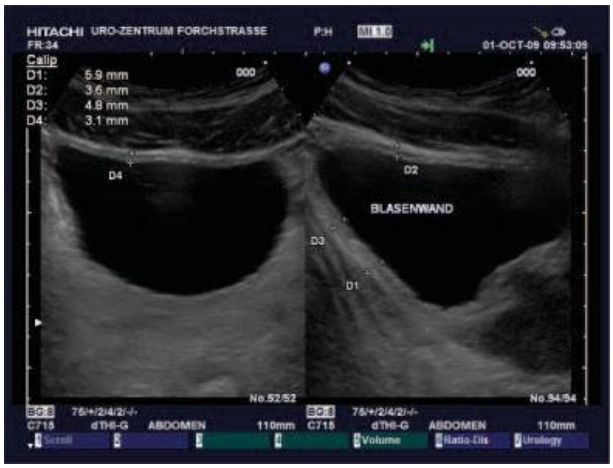
Figure 2 **Suprapubic transverse scan of the bladder in a young male. Dorsal to the bladder, the symmetrical seminal vesicles can be seen. Behind the bladder roof hyperechoic reverberation echoes are often seen. This ultrasound artefact is produced by multiple reflections of an object if the acoustic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



On ultrasound the bladder wall appears as a three layer structure. The detrusor muscle is of medium homogeneous echogenicity. The outer serosa (adventitia) layer and the inner

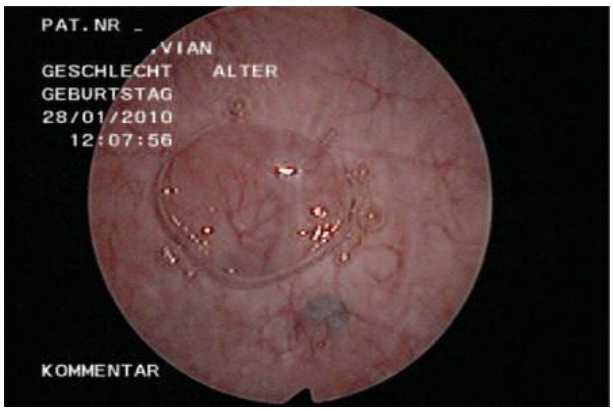
mucosa (urothelial) layer are hyperechoic compared with the middle detrusor smooth muscle (muscularis propria) layer [Figure 3].

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



When filled, a normal bladder wall should have a uniform appearance without any contour irregularity [Figure 4].

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 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 2.5−5 MHz probe. Most general ultrasound practitioners will have this type of abdominal probe as part of their standard equipment. The patient is examined in the supine position with a partially full bladder (200−300 ml). If it is necessary to obtain more detailed information of the bladder roof, linear probes with higher frequencies (7.5−16 MHz) can be used. The bladder floor and the distal and intramural part of the ureters 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 [Figures 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 mini probes 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.

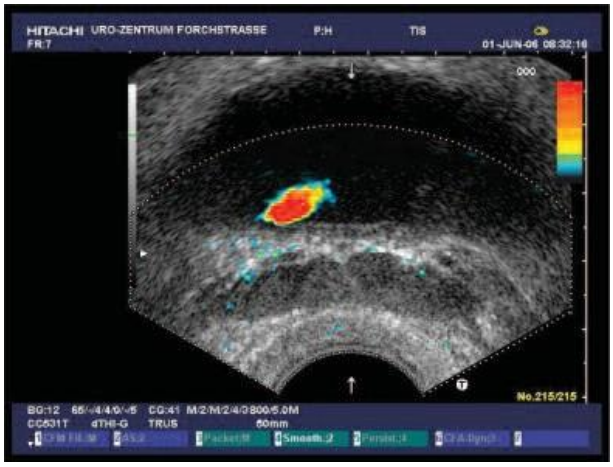
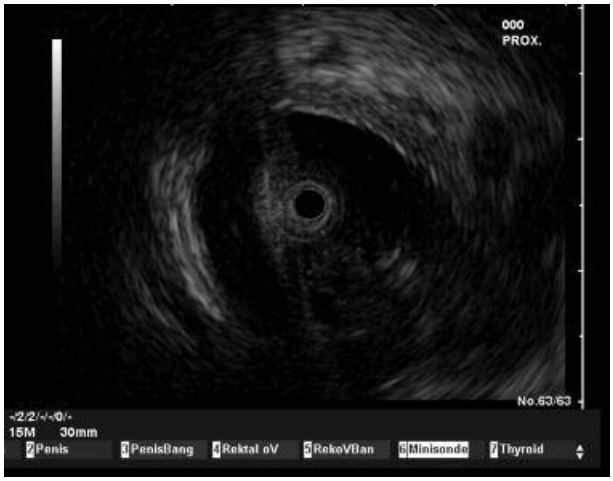


Figure 6 Endosonography with 360° high-frequency (20 MHz) mini probe with a 6-Fr diameter. Used for endourological staging of bladder cancer or urothelial cancer in the upper urinary tract, or in the detection of aberrant lower pole kidney vessels, which are responsible for ureteropelvic junction obstruction.



Diffuse bladder disease

Assessment of diffuse bladder disease should 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 cause in males is benign prostatic hyperplasia (BPH). BOO leads to lower urinary tract symptoms (LUTS), infections and bladder stones owing to residual post-void urine. The different inter-individual 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 upregulation 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 clinically irritative voiding and symptoms ranging from frequency and urgency to urge incontinence (known as overactive bladder symptoms (OAB)) owing to low bladder compliance with small capacity because of collagen deposition and over-activity. 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 on 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 nocturia, acute urinary retention or urinary overflow incontinence. Bladder compliance changes throughout the course of BOO are not yet fully understood; however, it is important to be aware that most of the symptoms of BOO, such as urgency, are caused by autonomous adaptation of the detrusor muscle to subvesical obstruction.

The following structures are assessed in sonographic evaluation of BOO:

- The bladder wall
- The bladder shape
- Bladder content.

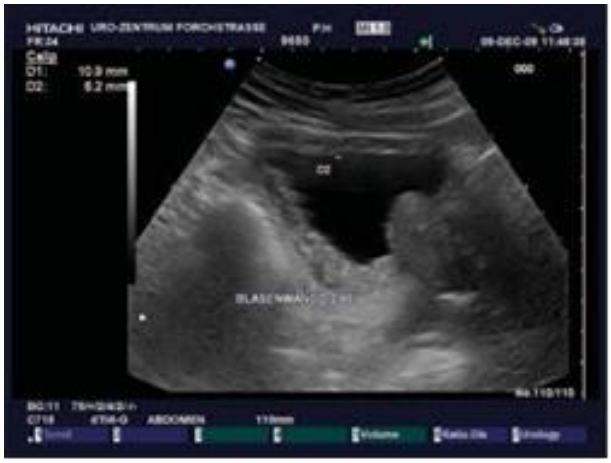
The bladder wall

Detrusor hypertrophy results in the 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 7.5 MHz probe (or the posterior wall with a TRUS probe) with a defined bladder volume of 100–300 ml. Unobstructed normal BWT was found to be 3.0 ± 1.1 mm. A strong correlation between BOO and a BWT of greater than 5 mm at 150 ml 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 the bladder volume for BWT measurement is not standardised [Figures 7 and 8].

Using BWT and bladder volume, the BWM can be calculated by multiplying the bladder volume by the wall thickness and the specific gravity of bladder tissue (0.957±0.026 g/cm^3). There is a cut-off weight for an obstructed bladder of >50 g. BWM of more than 80 g 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 accurate evaluation of bladder contractility and BOO is still the invasive and expensive urodynamic pressure-flow study.

Figure 7 **Bladder wall thickness (BWT) 6.2–10.9 mm in a male with benign prostatic hyperplasia stage 2 with a post-void residual urine volume of 60 ml. BPH with a prostate volume of 70 cm^3 and median lobe hyperplasia. Transrectal ultrasound biopsy could exclude the suspicion of malignancy because of elevated prostate specific antigen >4 ng/ml. BWT of more than 5 mm is suggestive of bladder outlet obstruction despite the measurement being taken after voiding and without the standardised bladder volume of 150 ml.**



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