REVIEW
ARTICLE

Ultrasonography of the Urinary Bladder

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The urinary bladder was one of the first of the body's systems to be investigated by ultrasound. The bladder can be scanned by the suprapubic transabdominal route, while the perineal and intravesical routes are practically not used. Ultrasonic visualization of the bladder and other pelvic structures necessitates a full bladder. The bladder must be examined when comfortably full. Ultrasonography is a convenient, safe and relatively inexpensive tool for urinary bladder examination. A wide variety of pathologies may involve the urinary bladder and these can be diagnosed by ultrasonography. However, comparatively less attention is paid to pathologies involving the bladder in the literature. We present the most common pathologies that may be encountered in day-to-day practice.

KEY WORDS — bladder wall, ultrasonography, urinary bladder

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Introduction

The urinary bladder is a hollow muscular organ that serves as a reservoir for urine. The adult bladder normally has a capacity of 400–500 mL. The ureters enter the bladder posteriorly in an oblique manner. The orifices are situated approximately 2.5 cm apart. The trigone occupies the area between the two orifices and the bladder neck.

In males, the bladder is related posteriorly to the seminal vesicles, vasa deferentia, ureters, and rectum. In females, the uterus and vagina are interposed between the bladder and the rectum. In both males and females, the bladder is related to the posterior surface of the pubic symphysis, and when distended, it is in contact with the lower abdominal wall.

The urinary bladder was one of the first of the body's systems to be investigated by ultrasound. The bladder can be scanned by the suprapubic transabdominal route, whereas the perineal and the intravesical routes are rarely used. Ultrasonic visualization of the bladder and other pelvic structures necessitates a full bladder. The bladder must be examined when comfortably full. An induced diuresis with oral or intravenous diuretics is practiced in some centers, but avoiding the use of diuretics is the preferred practice.

The full bladder on transverse scan appears as a thin-walled (2–3 mm) smooth structure, almost rectangular in configuration. The shape is usually

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symmetrical but the left lateral wall may be deformed by the sigmoid colon, particularly when filled with feces. On sagittal section, the bladder is triangular in shape (Fig. 1).

The ureteric orifices appear as small focal thickenings of the bladder base and urine can be seen jetting into the bladder with ureteric peristalsis (Fig. 2A). The jet phenomenon is best observed on color Doppler ultrasound if the patient is asked to drink an adequate amount of water (Fig. 2B). The visualization of these jets is probably due to differences in density between the ureteric and bladder urine. The fetal bladder can be seen from 16 weeks onwards.

Techniques of Examination

Adequate filling of the bladder can usually be achieved by drinking 4–5 glasses of water or other drinks 1 hour before the examination. A bladder that is too full may restrict the period of scanning due to the patient's discomfort. Therefore, in this circumstance it is always advisable to re-examine the patient after partial emptying of the bladder.

Equipment Requirements

Suprapubic transabdominal ultrasound with a 3.5–5 MHz transducer is ideal in all age groups. For neonates, 7.5 MHz transducers may be needed.

Bladder ultrasonography is used to assess the following [1]: (1) bladder wall anatomy (thickness and focal abnormalities, presence of trabeculation, and diverticula), (2) bladder capacity in milliliters, (3) anatomy of the bladder base, (4) distal ureteric anatomy, (5) post-micturition residual volume, and (6) intravesical filling defects.

Bladder Volume and Residual Urine

The main practical application of bladder volume estimations is in the assessment of residual urine. A significant increase in residual urine occurs in bladder neck obstruction and neurological disturbances. Bladder volumes are measured using the standard technique described by Poston [2], i.e. the bladder

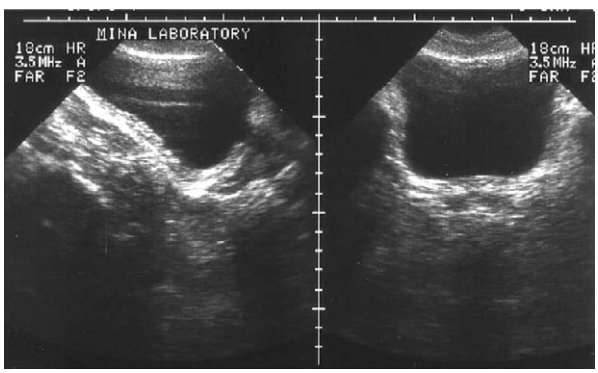

Fig. 1. *Normal bladder. Sagittal and transverse scans of the full bladder. The bladder wall is thin and bladder shapes are triangular and rectangular.*

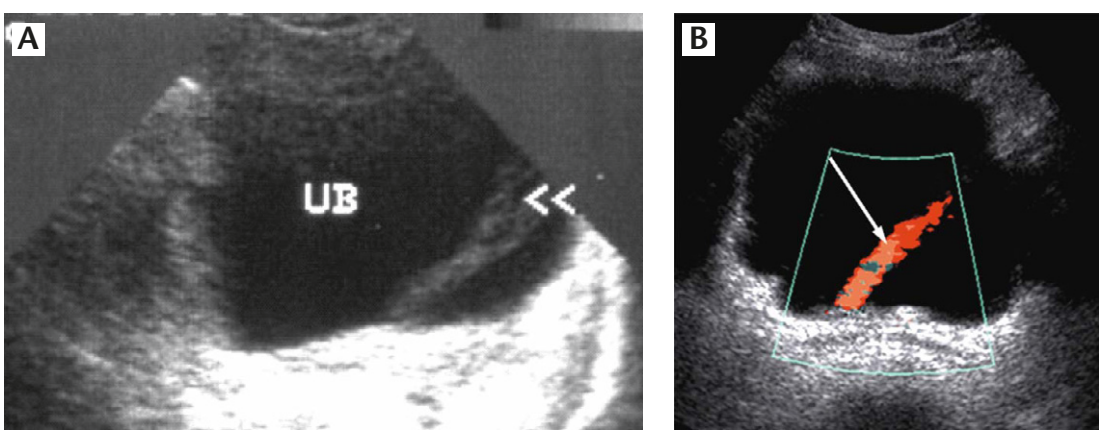

Fig. 2. *(A) Ureteric jet where urine can be seen jetting into the bladder with ureteric peristalsis. (B) Ureteric jet shown as color flow signals arising from the right distal ureter. It is better appreciated by color Doppler ultrasound (arrow).*

volume (V) in milliliters is $V = 0.7 (H \times D \times W)$ (where D = depth in the sagittal plane, H = maximum diameter in the sagittal plane, W = maximum transverse diameter in the transverse plane; all measurements are in centimeters).

For an initial investigation in a patient with a voiding disorder, an ultrasound cystodynamogram is the investigation of choice [3]. Once the full bladder is scanned and its volume measured, the patient voids into a standard flow rate machine, having been asked to void as normally as possible without superimposed abdominal straining. Immediately after voiding, the bladder is rescanned and any residual volume is measured. If there is a large residual volume (≥100 mL) the bladder should be rescanned after a second void and that residual urine volume assessed [1].

Bladder Tumors

Bladder cancer is the second most common cancer of the genitourinary tract. It accounts for 7% of new cancer cases in men and 2% of new cancer cases in women [4]. Bladder cancer, primarily a disease of men older than age 65, is rarely diagnosed before the age of 40 [5].

Cigarette smoking is the most important risk factor [6]. Cigarette smoking is believed to contribute to upwards of 50% of the bladder cancers in men and 33% of the bladder cancers in women. Overall, smokers have a 2–4-fold higher risk of bladder cancer than nonsmokers. Fried meats and fats consumed in high quantities are associated with bladder cancer [7]. A poorly understood variant of bladder cancer is carcinoma-*in-situ*, which presents with dysuria and frequency in the absence of infected urine. The diagnosis is histological, based on abnormal urine cytology or random biopsies taken at cystoscopy. No radiological abnormality is demonstrable. Half of these patients will develop invasive malignancy within 3 years [8].

Transitional cell tumors are usually slow growing and initially spread by local invasion. Once the perivesical fat has been invaded, the spread into the local lymph nodes and beyond occurs in 84% of patients [9]. Patient prognosis is related to the extent of tumor spread and accurate staging is needed. Five-year survival of patients with superficial tumors (T1, T2; Fig. 3) is 50–80%, whereas those with invasive malignancy can expect a 6–23% 5-year survival (Fig. 4) [10,11].

Squamous cell carcinomas and adenocarcinomas account for approximately 5% and 2% of malignant epithelial tumors of the bladder, respectively. Squamous carcinoma may complicate chronic irritative conditions and may be more infiltrative on ultrasonogram, and adenocarcinomas tend to be ulcerative (Fig. 5). Lymphoma of the bladder is a rare condition.

Once a bladder tumor has been diagnosed, the main application of ultrasonography in the assessment of bladder tumors is in staging the tumor. The stage of the tumor greatly influences the method of treatment and prognosis. Extension of the tumor

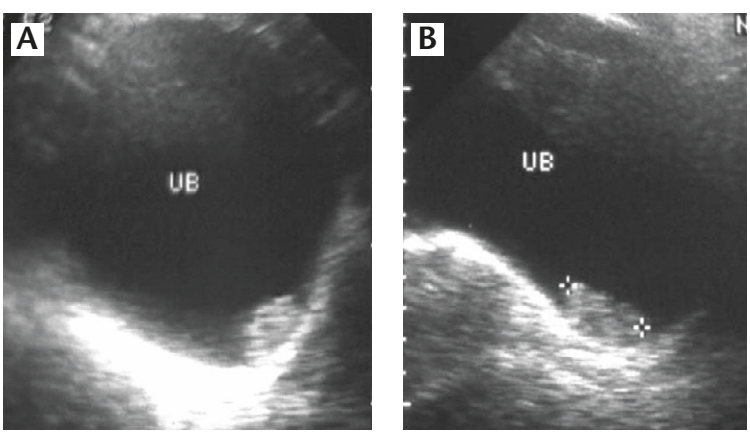

Fig. 3. *Superficial bladder cancer that does not disrupt the normal bladder wall. This is a T1 or T2 malignancy. UB = urinary bladder.*

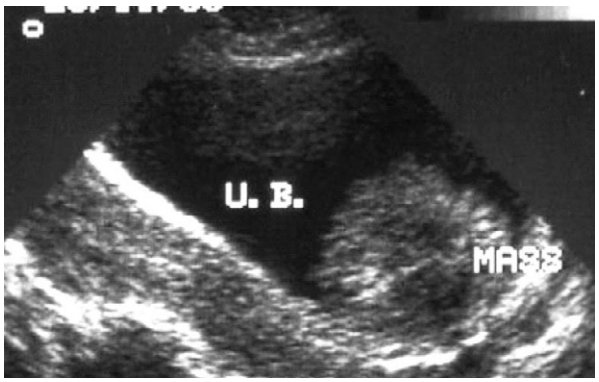

Fig. 4. *T3 and T4 bladder cancer. There is disruption of the normal bladder wall echoes and this mass is of considerable size. UB = urinary bladder.*

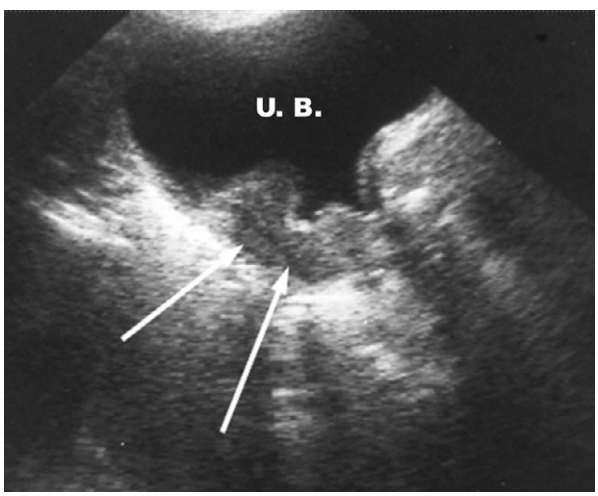

Fig. 5. *Bladder adenocarcinoma. The tumor located in the bladder base (arrows) is associated with a superficial ulceration.*

to the deep muscle layer is of serious prognostic significance (Table 1 [12]).

A high degree of accuracy has been claimed for both endoscopic and transabdominal ultrasonography [13–15]. Superficial bladder tumors project in the bladder lumen from the mucosa layer of the bladder. Broad-based bladder tumors are larger-sized and involve deep muscle layers. Bladder wall edema associated with chronic catheterization, chronic cystitis and a hypertrophied bladder wall cannot accurately be distinguished from a solid tumor [16,17]. Overall, the noninvasive suprapubic approach gives similar results to invasive endoscopic ultrasound. For larger tumors, lower frequency abdominal probes are necessary for better penetration and more accurate staging.

Table 1. TNM classification for staging bladder carcinoma [12]

Category T	
TIS	Pre-invasive carcinoma (carcinoma *in situ*)
TA	Papillary noninvasive carcinoma
T0	No evidence of primary tumor
T1	Tumor does not extend beyond the lamina propria; if a mass is palpable, it should be freely mobile and should disappear completely after transurethral resection
T2	Tumor involves superficial muscle; mobile bladder indurations that disappear after complete resection
T3	Tumor invades into deep muscle
T3a	Tumor invades deep muscle alone
T3b	Tumor extends through bladder wall
T4	Tumor fixed or extending into neighboring structures

TNM = tumor, nodes, metastasis.

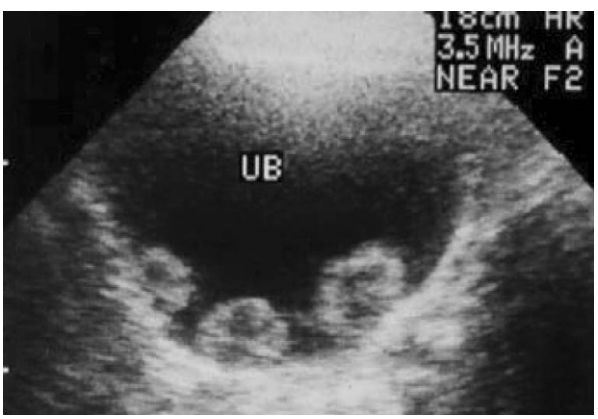

Fig. 6. *Bladder tumor recurrence. The natural characteristic of an urothelial tumor is recurrence. Recurrences develop at multiple sites postoperatively.*

The natural characteristic of an urothelial tumor is recurrence (Fig. 6) [5]. Recurrences may develop at any time, at the same or separate site of the urothelial tract, and at the same or more advanced stage. Regular follow-up after treatment is necessary.

A combination of suprapubic bladder ultrasonography and transrectal ultrasonography can replace any type of cystoscopy; the combination is much preferred by the patient and much cheaper [17].

Any focal abnormality seen on ultrasonographic results requires cystoscopy for confirmation and biopsy.

Secondary involvement of the bladder involving tumors mostly occurs by direct spread from a carcinoma of the cervix, prostate or rectum. Less common secondary tumors develop in the bladder by seeding from primary tumors of the upper urinary tract.

Benign bladder tumors are rare. Primary benign tumors are often hypoechoic compared with malignant tumors. However, in practice, a similar appearance may be produced by all these pathologies and a definite diagnosis can only be made by cystoscopic biopsy. In females, endometriosis may involve the bladder on rare occasions. In this case, it is very difficult to differentiate it from bladder tumors.

Bladder Infection

Acute cystitis more commonly affects women than men. The primary mode of infection is from periurethral, vaginal or fecal flora. The diagnosis is made clinically. In severe cases, the three-layer sign of the bladder wall and debris in urine may be seen (Fig. 7).

Recurrent cystitis is caused by bacterial persistence. Identification of the cause of the recurrent infection is important [5]. Ultrasonography can be obtained to provide a screening evaluation of the genitourinary tract.

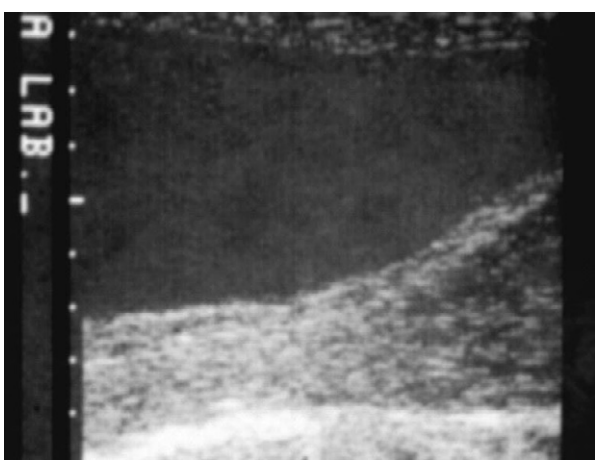

Fig. 7. *Acute cystitis. In severe cases, the three-layer sign of the bladder wall and debris in the urine are seen.*

Urography should only be performed in patients with high-risk factors, e.g. hematuria, calculous disease or biochemical evidence of altered renal function [18]. Bladder ultrasonography combined with a plain film of the abdomen and renal ultrasonography is now established as the initial investigation in the assessment of children with urinary tract infections [19].

The inflammatory process usually extends beneath the mucosa into the submucosal and muscular layers of the bladder and may be associated with white cell infiltration. Varying degrees of fibrosis, which compromises detrusor function, may decrease bladder capacity and/or accumulation of residual urine. On ultrasonographic examinations, the bladder inner wall is found to be irregular, urine may contain fine suspended echoes with varying amounts of postvoidal residual urine (Fig. 8). Ultrasonography can diagnose predisposing factors, e.g. bladder calculi, tumors, an enlarged prostate, diverticula, or neurogenic bladder. Female lower tract infections are more likely to be associated with functional than anatomical abnormalities.

Vesicoureteric reflux is found in 20–30% of children with proven urinary tract infections and leads to renal scarring, reflux nephropathy, end-stage renal failure and hypertension. Micturating cystography is the traditional method of investigation, but ultrasound cystography is an attractive alternative.

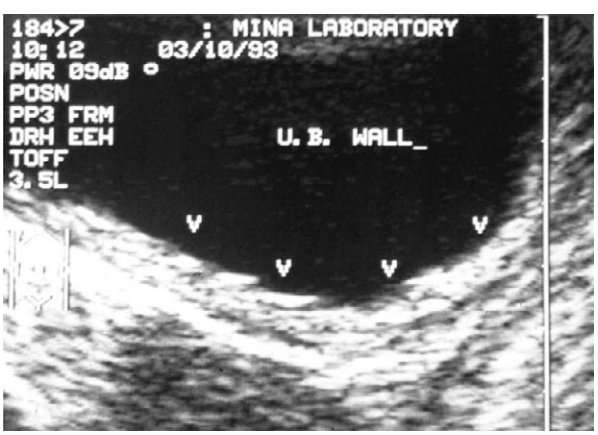

Fig. 8. *Recurrent cystitis. On ultrasonographic examination, the bladder inner wall is found to be irregular, urine may contain fine suspended echoes, and a varying amount of post-void residual urine. UB = urinary bladder.*

Patients with an over-distended bladder have a dilated pelvicalyceal system of one or both kidneys. After voiding urine, the kidneys show no dilatation of calyces. These patients usually have grade 3 or 4 reflux. Some studies have shown ultrasonography to be 100% sensitive for the diagnosis of grade 3 and 4 reflux [20]. Ultrasound cystography cannot detect grade 1 or 2 reflux, nor does it give much indication of urethral anatomy [21].

Bladder Diverticula

Bladder diverticula may be congenital or acquired. Acquired diverticula are more common in males, are usually para-ureteric and associated with vesico-ureteric reflux. Acquired diverticula are virtually always associated with urinary outflow obstruction. The wall of the distended bladder is quite smooth. When there is hypertrophy due to chronic obstruction, individual muscle bundles become taut and give a coarsely interwoven appearance to the mucosal surface. This is called trabeculation. Normal intravesical pressure is approximately equal to that of 30 cm of water at the beginning of micturition. Pressures two to four times as great may be reached by the trabeculated bladder in an attempt to force urine past the obstruction. This pressure tends to push mucosa between the superficial muscle bundles, causing the formation of small pockets or cellules (Fig. 9).

If cellules force their way entirely through the musculature of the bladder wall, they become diverticula. Diverticula have no muscle wall and are therefore unable to expel their contents into the bladder efficiently. Eighty-five percent of diverticula arise just lateral and superior to the ureteric orifice and can achieve enormous sizes (Fig. 10A). Calculi commonly form in them because of stasis and 5% are associated with a transitional cell tumor [22] (Fig. 10B).

Ultrasonography can rapidly confirm the presence of a diverticulum and to what extent it empties following micturition. In some patients, the diverticulum may increase in size during micturition as the bladder empties into it rather than through an

Fig. 9. *Bladder cellules. Acquired diverticula are virtually associated with urinary outflow obstruction. Increased pressure inside the bladder tends to push mucosa between the superficial muscle bundles causing the formation of small pockets or cellules. UB = urinary bladder.*

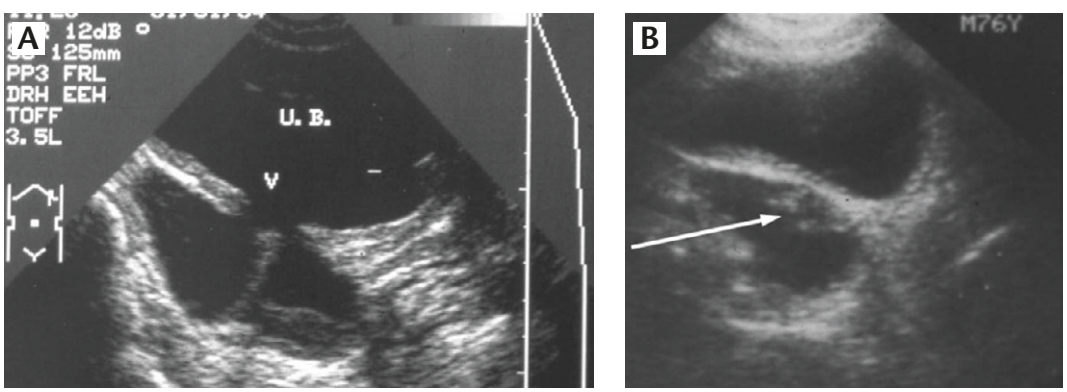

Fig. 10. *Bladder diverticulum. (A) There is a large diverticulum posteriorly and the ostium is easily identified. The true bladder wall is thickened and slightly trabeculated. The wall of the diverticulum is smooth and contains debris. (B) Bladder diverticulum with urothelial carcinoma. A focal tumor can be seen with an irregular surface (arrow) that developed in a large diverticulum, which is located posteriorly to the urinary bladder.*

obstructed lower tract. The position and size of the orifice can help preoperative planning. The most important use of ultrasound is to detect complications such as stones or tumors.

Bladder Stones

Most bladder stones are seen in men. In developing countries, they are found in prepubescent boys. The incidence of bladder stones has decreased during the last 50 years, probably due to a change of food habits. Bladder stones usually are a manifestation of an underlying pathological condition, including voiding dysfunction, foreign bodies, and infections; kidney stones may pass through the ureter and come into the bladder.

Bladder stones appear as highly reflective masses within the bladder, move with altered posture and cast shadows (Fig. 11). Bladder tumors can calcify but do not move. Stones can be multiple and are always associated with outflow obstruction. Stones complicating diverticula are common. Bladder stones may occlude the bladder outlet at the internal urethral meatus. Small stones may pass through and can be lodged anywhere in the urethra.

Ureterocele

A ureterocele is a saccular protrusion of terminal part of ureter into bladder. Ectopic ureteroceles can arise anywhere in the lower urogenital tract [23]. Ureterocele occurs seven times more often in females than in males, and approximately 10% of cases are bilateral. There is nearly always significant dilatation of the ureter and calyces. Cystic dilatation forms between the superficial and deep muscle layers of the trigone. They are easily seen on both suprapubic and transrectal ultrasonography. Ureteroceles appear as a "cyst within a cyst" (Fig. 12). Mostly, they

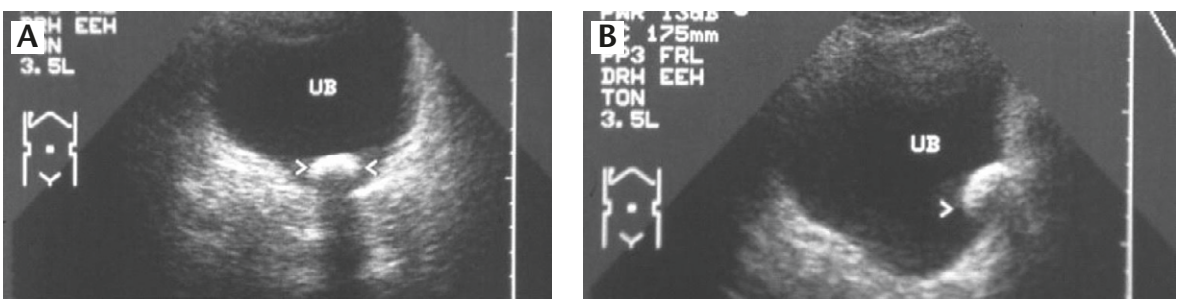

Fig. 11. *Bladder stone. Transverse scan of the bladder. There is a highly reflective focus with acoustic shadowing characteristic of a bladder stone. The stone moves with repositioning of the patient.*

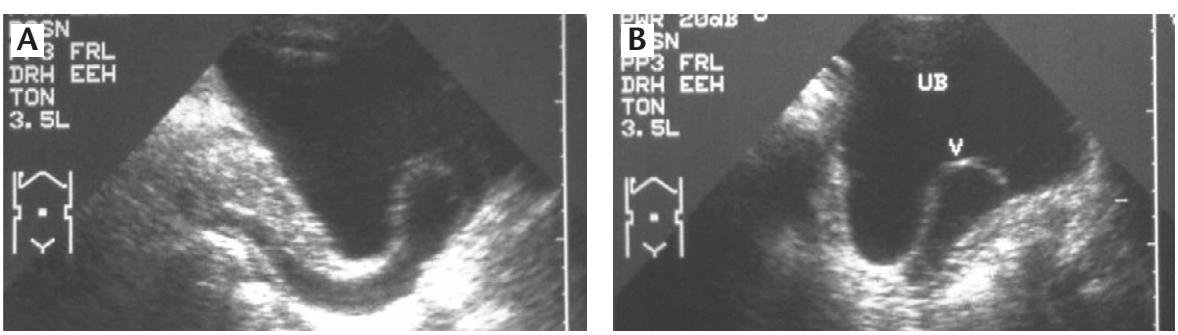

Fig. 12. *Ureterocele. Sagittal section of the bladder showing a well-defined cystic lesion overlying the ureteric orifice. A dilated distal ureter is also seen.*

are dynamic and gradually increase in size with accumulation of urine and then collapse. When the walls of the cystocele are very thin, they can be easily missed and careful scanning is needed.

Blood Clots

In patients with clots and hematuria, ultrasonography is useful for assessing how much clotting remains within the bladder. Echogenic structures within the bladder without shadows and show change of position with change of body posture are typical ultrasonographic findings for blood clots (Fig. 13A). Care must be taken to differentiate a mobile intravesical clot from a sessile bladder tumor by examining the patient supine and decubitus (Figs. 13B and 13C). When a blood clot remains attached to the bladder wall, it can be unclear whether it is bladder mass or a clot. Color Doppler ultrasonography can be used to distinguish tumors from clots. A tumor may show color flow signals, while a blood clot does not (Fig. 14).

Foreign Bodies

Numerous objects have been found in bladder of both males and females. Some of them find their way into the urethra in course of inquisitive self-exploration [24]. The presence of foreign bodies causes cystitis and hematuria. Ultrasound can detect such objects. Embarrassment may cause the victim to delay medical consultation, and they are often found incidentally in the assessment of patients with hematuria or urinary tract infections.

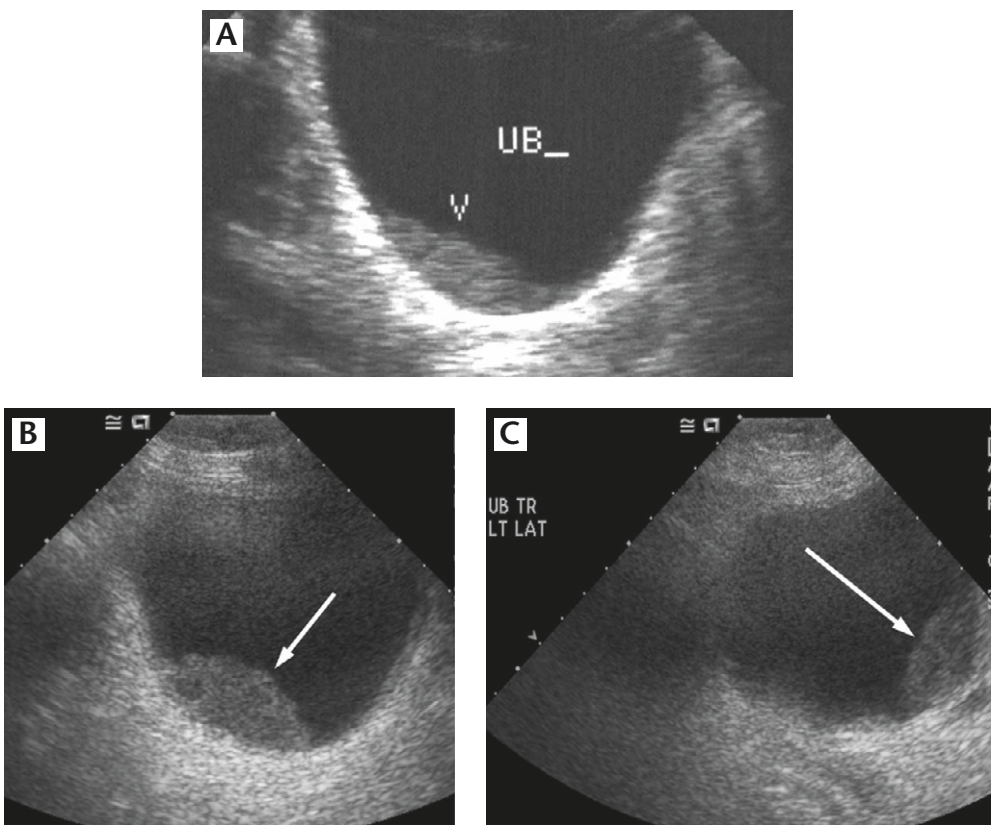

Fig. 13. *Blood clot. (A) In the transverse section of the bladder, an echogenic structure without shadows is attached to the wall. This should move with repositioning of the patient. (B) On routine transverse scan of the urinary bladder, the clots (arrow) appear as echogenic structures without shadows in the dependent portion of the urinary bladder. (C) When the patient changes his posture from the supine to the left decubitus position, the clots (arrow) are repositioned in the left aspect, the new dependent portion of the bladder.*

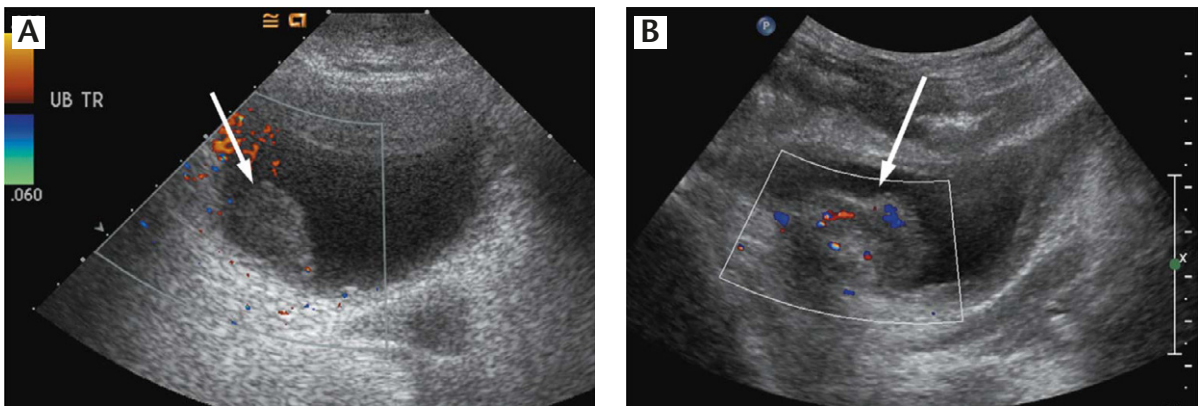

Fig. 14. *Differentiation between attached clots and bladder tumor (cancer). (A) A clot is attached on the right lateral bladder base. Color Doppler ultrasonography shows no color flow signals (arrow). (B) In another patient with bladder cancer, the tumor (arrow) shows the presence of color flow signals.*

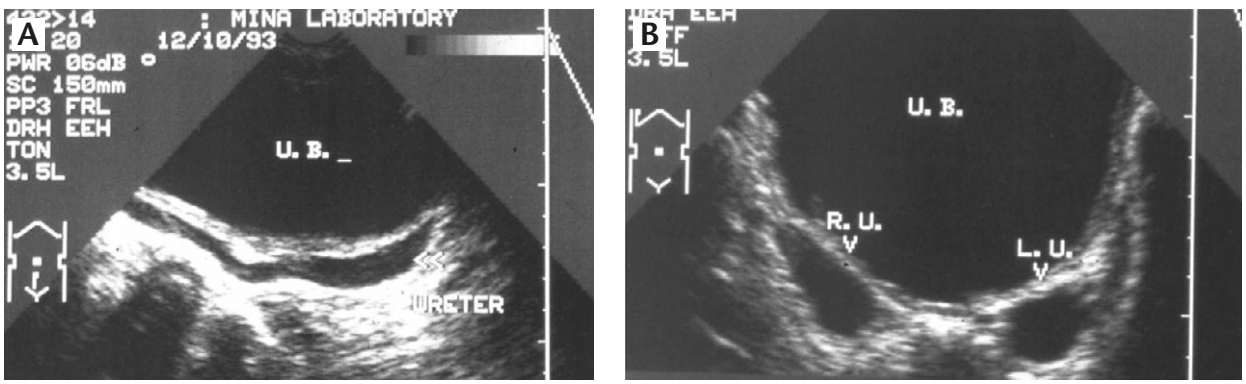

Fig. 15. *Dilated ureter. (A) Sagittal scan of the bladder. The tubular structure behind the well-filled bladder is a dilated ureter. (B) Transverse scan of the bladder. Transverse sections of both the dilated ureters are seen behind a well-filled bladder.*

Distal Ureters

Normal ureters are not visualized by ultrasound. However, when the ureter is dilated, the distal third portion can be visualized posterior to a well distended bladder (Fig. 15A). The ureteropelvic junction is the narrowest part of the ureter. A ureteric stone lodged at this point can be detected. A bladder mass at the vesicoureteric junction results in dilation of the ureter of the affected side. Obstruction at the bladder outlet causes dilatation of both the ureters (Fig. 15B). Currently, most kidney stones are treated by extracorporeal shock wave therapy where the stone is fragmented into small pieces or into stone sands. These fragmented parts pass through the ureter and may accumulate at the distal ureter causing temporary obstruction. Ultrasonography can be used to follow up these patients.

Conclusions

The urinary bladder is a hollow viscus with the shape of a four-sided inverted pyramid when empty and of a rounded structure when distended. When properly distended with urine, the bladder is an organ suitable for a thorough transabdominal ultrasonographic evaluation. Understanding the layers and regional anatomy of the bladder will help assess the mucosal, mural and juxtabladder pathologies. Disorders such as urachal lesions, bladder tumors or cancers, diverticulosis, and lithiasis can

usually be well demonstrated with ultrasonography. However, some pathologies may show nonspecific findings including endometriosis, amyloidosis, polypoid cystitis, granulomas and inflammatory pseudotumor. Benign tumors (e.g. inverted papilloma, villous adenoma, condyloma acuminatum) may not be distinguished from malignant bladder tumors. In that instance, cystoscopy may be necessary for differentiation and for providing cytological or histological diagnosis.

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