REVIEW ARTICLE

Ultrasound of the Urinary Bladder, Revisited

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Urine-filled bladder can be evaluated easily with ultrasound, and bladder tumors are usually well shown at ultrasound. Although ultrasound is not a primary imaging modality for staging of bladder tumors, it can provide general information regarding depth of tumor invasion into the proper muscle or perivesical adipose tissue. Ultrasound is also useful in showing nonneoplastic lesions of the bladder, such as stone, cystitis, diverticulum and ureterocele. Color Doppler ultrasound can show vascularity of the tumor. It also shows urine flow from the ureteral orifice or through the diverticular neck. As compared with transabdominal ultrasound, transrectal ultrasound shows bladder lesions more markedly in the dorsal wall or neck of the bladder.

KEY WORDS — ultrasonography, urinary bladder, urogenital system

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Introduction

Ultrasound is a useful noninvasive imaging modality in evaluation of the urinary bladder. Post-voiding residual urine may be measured accurately by ultrasound. The urine-filled bladder provides excellent acoustic window for evaluation of the bladder itself and adjacent organs as well. When doing an ultrasound examination of the kidney for evaluation of hematuria, urinary bladder should also be imaged to detect unsuspected tumors or stones.

Polypoid tumors are well detected with bladder ultrasound, and ultrasound is much more sensitive in detecting bladder tumor, compared with intravenous urography [1]. However, infiltrative tumors may not be detected at ultrasound, or it may be difficult to differentiate them from non-neoplastic lesions. Three-dimensional ultrasound and ultrasound-based virtual cystoscopy may be better than two-dimensional ultrasound in detecting bladder tumors [2,3]. Transrectal ultrasound shows tumors involving dorsal wall or neck of the bladder better than transabdominal ultrasound. Transurethral ultrasound is probably the best technique for evaluation of the depth of tumor invasion into the bladder wall, to distinguish superficial from deep infiltrating tumors, but it is an invasive technique [4].

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Normal Urinary Bladder

Bladder wall consists of mucosa, submucosa, lamina propria, and smooth muscle. The bladder wall musculature consists of three layers: an inner longitudinal, a middle circular and an outer longitudinal layer. Bladder muscles are highly echogenic, and urothelium and submucosal layers are indistinguishable unless separated by edema [4]. Bladder wall thickness varies with the state of urine filling, and the upper limits are 3 and 5 mm for a full bladder and empty bladder, respectively [5]. Its base is anchored inferiorly by the urogenital diaphragm. Ventrally, it borders with the symphysis pubis, dorsally with the rectum or vagina, and laterally with the perivesical fat and connective tissue. The dome of the bladder is covered by peritoneum. The shape of the bladder varies according to the patient's position and degree of urine filling.

The trigone is a triangular area between the two ureteral orifices and the internal urethral opening. Between the ureteral orifices, the musculature of the bladder floor is hypertrophied, forming the interureteric ridge. Interureteric ridge appears elevated at ultrasound, and ureteral orifices may mimic small bladder tumors in both longitudinal and transverse images (Fig. 1). Color or power Doppler ultrasound may show urine jetting from the ureteral orifices (Fig. 2). This finding of ureteral jet virtually excludes the possibility of significant obstruction of the ipsilateral urinary tract.

Measurement of Residual Urine

The amount of postvoiding residual urine is important information in patients with bladder outlet obstruction or neurogenic bladder. Ultrasound is a noninvasive method of measuring postvoiding residual urine. Residual volume is calculated by using a prolate ellipse formula: $v = 4/3\pi \times r1 \times r2 \times r3$. Ultrasound measurement is highly accurate when calculated volume is high, but error rate is high at lower volume [4,6].

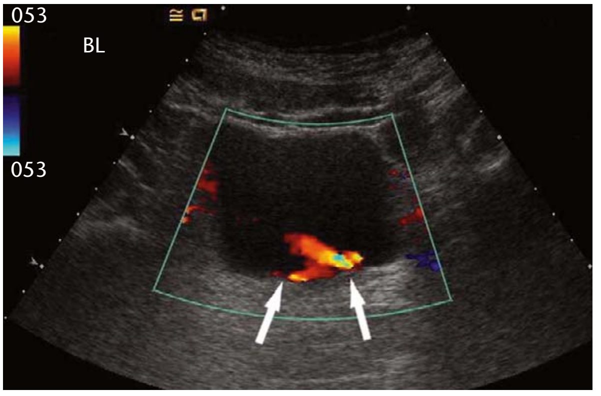


Fig. 2. *Ureteral jet on color Doppler ultrasound (CDUS) in a 49-year-old man. CDUS of the bladder (BL) in transverse plane shows jetting of urine from both ureteral orifices (arrows).*

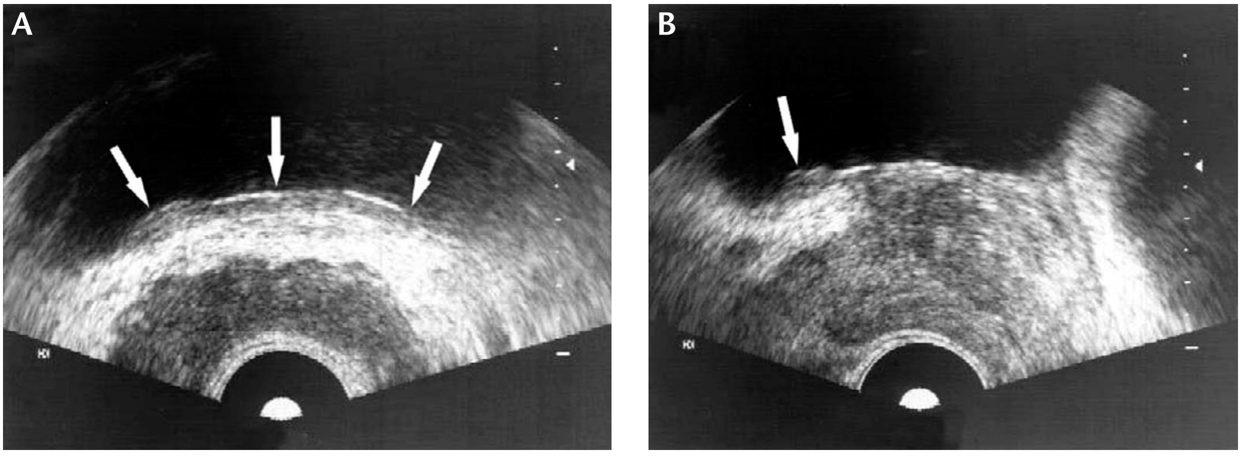


Fig. 1. *Normal bladder on ultrasound in a 67-year-old man. (A) Ultrasound of bladder in transverse plane shows slight elevated bladder mucosa at interureteric ridge (arrows). (B) Ultrasound of bladder in parasagittal plane shows localized bulging of the bladder mucosa at the ureterovesical junction (arrow).*

Bladder Tumors

Transitional cell carcinoma

Most bladder tumors are transitional cell carcinomas, accounting for about 90% of all primary malignant lesions. Men are affected more often than women, and about one-third of the bladder transitional cell carcinomas are multifocal at the time of diagnosis (Fig. 3). They arise most commonly in the region of the trigone or bladder base, or on the lateral walls. They show various patterns in growth, including papillary, infiltrative, and mixed papillary and infiltrative [7]. At ultrasound, they appear as polypoid or plaque lesions. Bladder inflammation, edema or postoperative changes may mimic flat infiltrative tumors [8]. Bladder tumors projecting into the lumen is usually quite echogenic and remains fixed with the change of the patient's position. This finding is different from bladder hematoma that moves with the patient's position change.

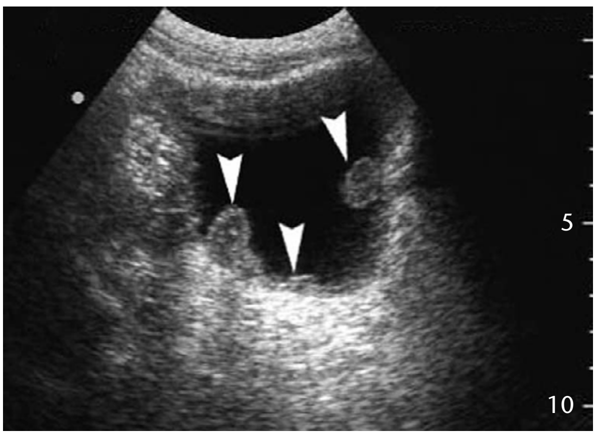


Fig. 3. *Multiple transitional cell carcinomas of the bladder in a 74-year-old man. Ultrasound of the bladder in transverse plane shows multiple papillary tumors (arrowheads) in the bladder.*

Transitional cell carcinomas often have calcification that is due to dystrophic calcification, usually in the necrotic surface of the tumor. Calcified bladder tumor shows posterior sonic shadowing and twinkling artifacts that occur when crystalloid material or rough surface of a lesion is interrogated with color or power Doppler ultrasound [9] (Fig. 4). Calcified bladder tumor should be differentiated from bladder stone by its nondependent location and absence of movement with the patient's position change.

Sometimes, bladder tumors are found at transrectal ultrasound that was performed to evaluate the prostate. Small bladder tumors in the trigone or neck area are especially well shown at transrectal ultrasound (Fig. 5). Color Doppler ultrasound (CDUS) shows vascularity of the tumor and often shows linear vessels in the pedicle of the tumor. CDUS is useful in differentiating tumor from blood clot by showing the absence of vascularity in the clot. In one study, the vascularity of the tumor seen at CDUS had no relationship with the tumor stage or histopathologic grade [10].

The depth of invasion into the wall and the involvement of adjacent organs are most important elements of staging of bladder cancer. Ultrasound is

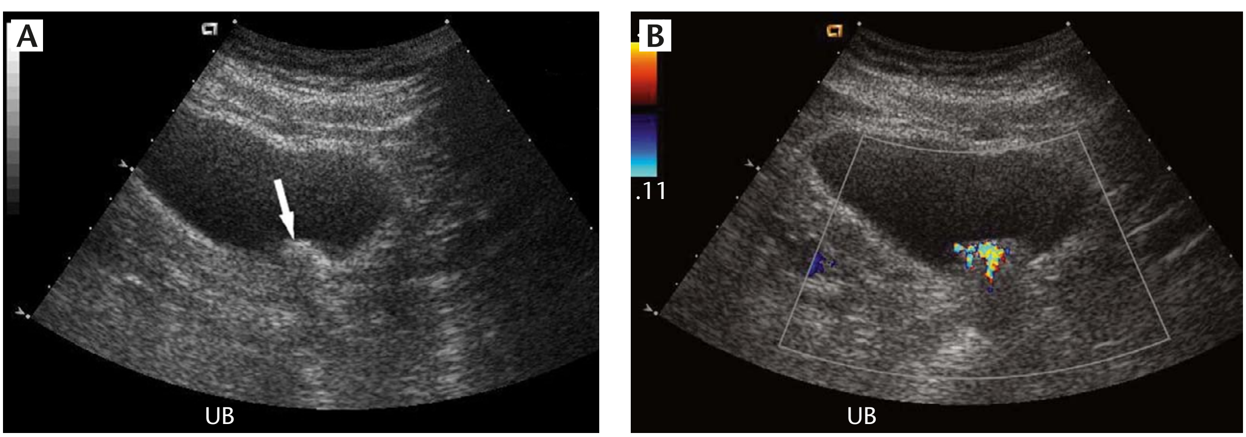


Fig. 4. *Calcified transitional cell carcinoma of the bladder in a 54-year-old man. (A) Longitudinal ultrasound of the bladder shows a mass with echogenic surface (arrow) and posterior sonic shadowing, suggesting a calcified mass. (B) Color Doppler ultrasound shows twinkling artifact occurring at the surface of the lesion, suggesting calcification. UB = urinary bladder.*

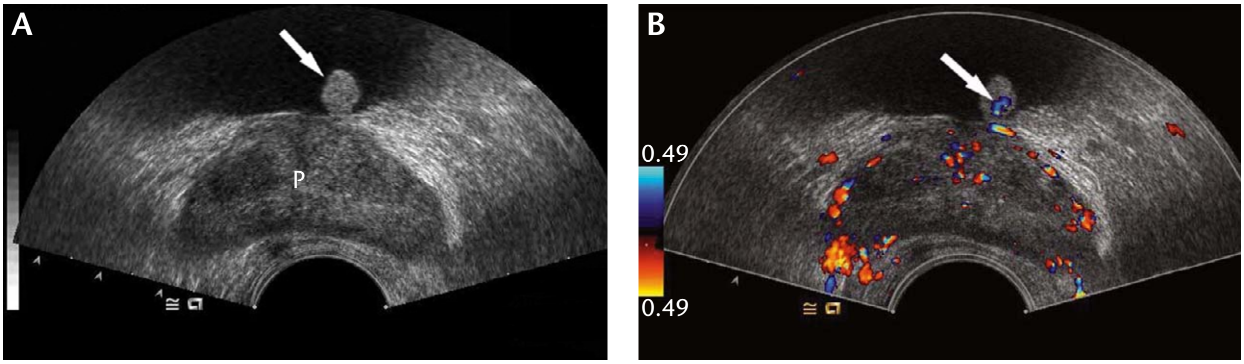


Fig. 5. *Small transitional cell carcinoma near the neck of the bladder in a 47-year-old man. (A) Transrectal ultrasound in transverse plane shows a small polypoid mass (arrow) near the bladder neck. (B) Color Doppler ultrasound shows a vessel in the pedicle of the mass (arrow). P=prostate.*

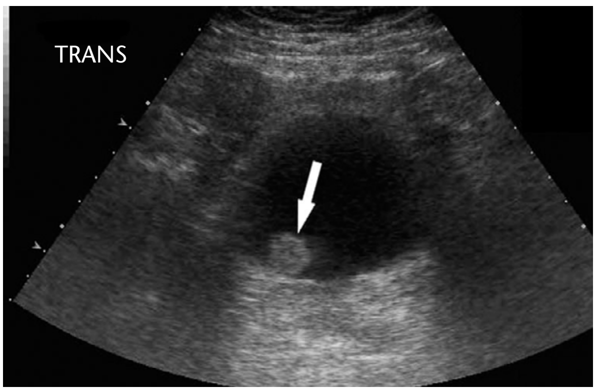


Fig. 6. *Superficial transitional cell carcinoma without stromal invasion in a 71-year-old man. Ultrasound of the bladder in transverse (TRANS) plane shows a polypoid mass (arrow) without any change of bladder contour.*

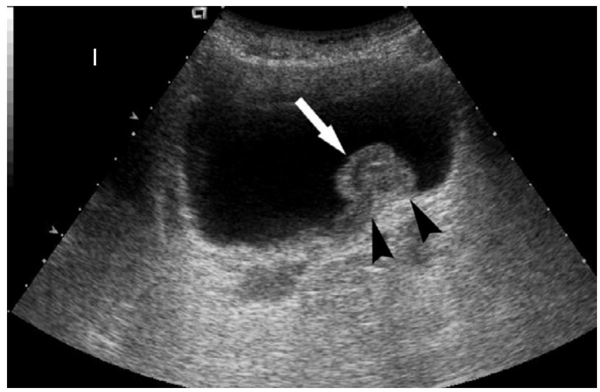


Fig. 7. *Transitional cell carcinoma of the bladder with invasion of proper muscle in a 62-year-old man. Ultrasound of the bladder in transverse plane shows a polypoid mass (arrow). In addition, contour of the bladder beneath the tumor is distorted (arrowheads), indicating invasion of proper muscle.*

not an imaging modality for staging of bladder tumor, but the depth of invasion of the tumor into the proper muscle and perivesical adipose tissue can be suggested [11,12]. Papillary tumor without contour deformity of the bladder indicates no significant invasion of the underlying muscle (Fig. 6). Tumor with invasion into the proper muscle shows rigidity and deformity of the contour of the bladder beneath the tumor (Fig. 7). Involvement of perivesical adipose tissue can be suggested when the tumor extends out of the expected contour of the bladder (Fig. 8). Transrectal ultrasound may show extension of the bladder tumor to the prostate, by showing ill-demarcated hypoechoic lesion in the prostate continuous with the bladder tumor. CDUS may show prominent vessels at the interface between the tumor and the prostate, indicating invasion of the prostate by the tumor.

Other primary tumors of the bladder

Squamous cell carcinomas represent 5% of bladder cancers and the most common nontransitional cell tumor of the bladder. They are usually associated with chronic irritation from urinary calculi, long-term indwelling catheters, chronic or recurrent infection, and schistosomiasis. Although squamous cell carcinomas cannot be differentiated radiologically from transitional cell carcinomas, they usually appear as sessile masses with or without extravesical extension. Papillary tumors or predominantly intravesical growth patterns are not typical for squamous cell

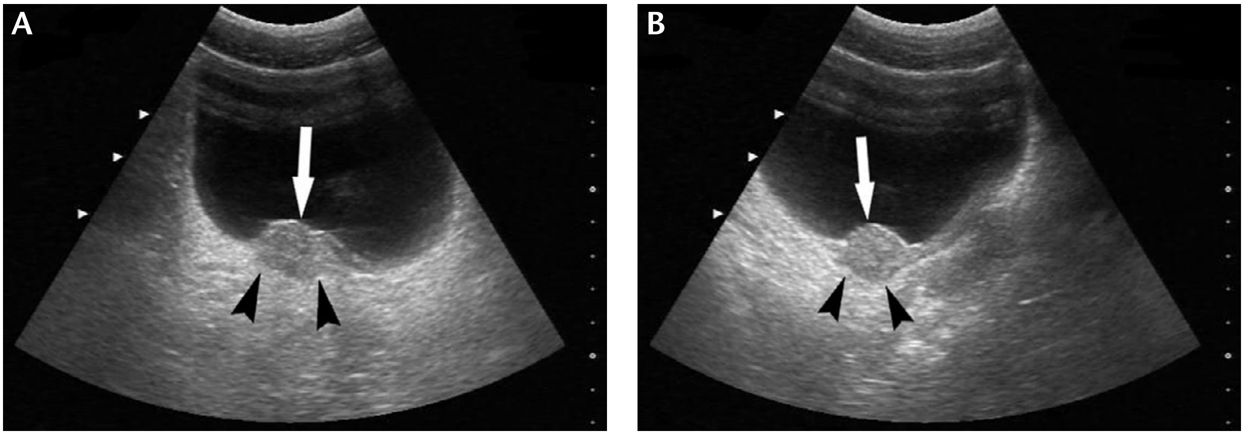


Fig. 8. *Invasive transitional cell carcinoma of the bladder with extension to perivesical adipose tissue in a 38-year-old man. (A) Transverse and (B) Longitudinal ultrasound images of the bladder show a broad-based tumor (arrow) in the posterior wall. Note that the tumor extends out of the expected contour of the bladder (arrowheads).*

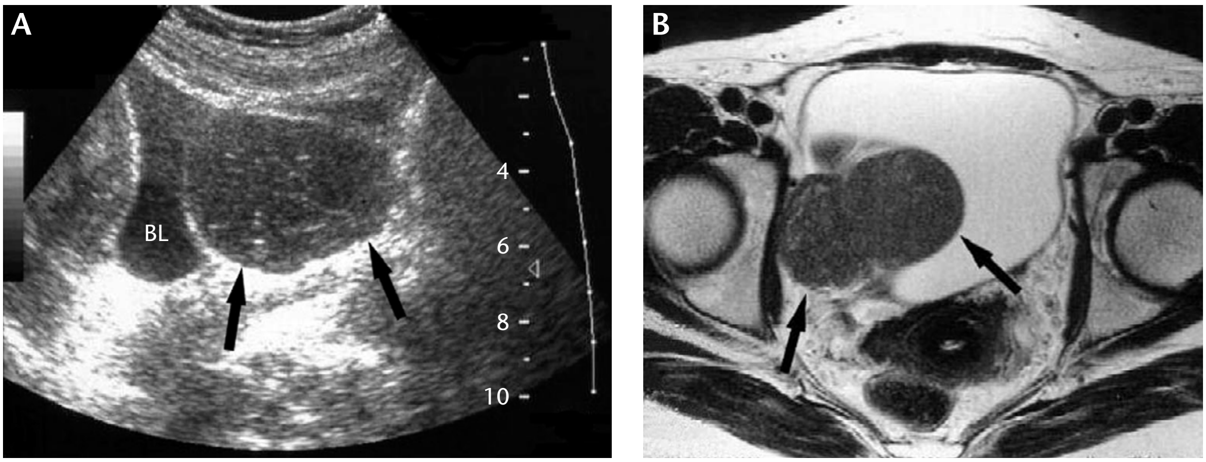


Fig. 9. *Leiomyoma of the bladder in a 40-year-old woman. (A) Ultrasound of the bladder in parasagittal longitudinal plane shows a well-demarcated mass of homogeneous intermediate echogenicity (arrows) in the posterior wall of the bladder. Note that the mass bulges both inside and outside of the bladder (BL). T2-weighted magnetic resonance image in transverse plane shows a homogeneous low-intensity mass with lobulated margin in the right posterior wall of the bladder (arrows).*

carcinomas. Prognosis of this tumor is poor because of the tendency to show early infiltration. Adenocarcinomas account for less than 2% of bladder cancers. They commonly occur in the dome and trigone of the bladder [7,13]. Adenocarcinomas may be associated with chronic irritation. Cystitis glandularis, bladder exstrophy, and urachal remnants are also associated with adenocarcinoma of the bladder [13]. Calcification is more commonly seen in adenocarcinomas than in other tumors. Other rare carcinomas of the bladder are small cell carcinoma and carcinosarcoma [7].

Leiomyomas are the most common nonepithelial benign bladder tumors. They are characterized by slow and noninvasive growth, without destruction of the overlying mucosa (Fig. 9). The other benign nonepithelial tumors of the bladder include neurofibromas, ganglioneuromas, and extraadrenal pheochromocytomas (paragangliomas) [7,14,15]. These tumors are nonepithelial mesenchymal tumors, and ultrasound usually shows well-demarcated, lobulated, hypoechoic mass in the bladder wall bulging both inside and outside of the bladder (Fig. 10). Hemangioma is a benign

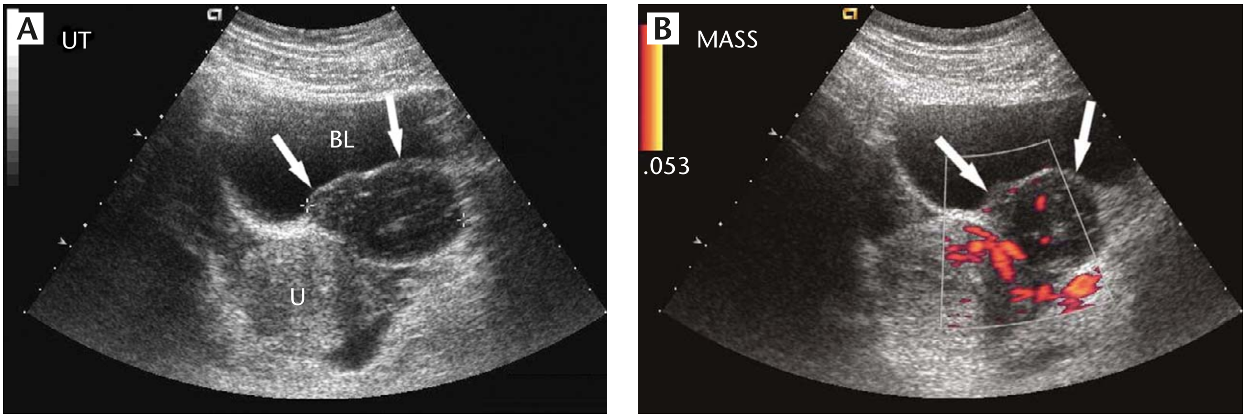


Fig. 10. *Neurofibroma of the bladder in a 25-year-old woman. (A) Ultrasound of the pelvic cavity in transverse plane shows a well-demarcated mass (arrows) in the left posterior wall of the bladder (BL). The mass is relatively hypoechoic as compared with the uterus (U), but has scattered hyperechoic foci. (B) Power Doppler ultrasound shows uterine vessels between the mass (arrows) and the uterus. The mass has a small amount of vascularity in it. (C) T2-weighted magnetic resonance image in transverse plane shows that the mass has heterogeneous signal intensity. Note that the low-intensity bladder wall is separated by the mass (arrowheads), indicating that the origin of the mass is the bladder wall.*

congenital tumor commonly occurring in children and young adults. The most common histologic type is cavernous hemangioma, and the other types are capillary and venous hemangiomas. Most of them involve submucosa and detrusor muscle. Bladder hemangiomas usually appear hyperechoic at ultrasound. They are often calcified, and ultrasound shows posterior sonic shadowing (Fig. 11).

Rare sarcomas of the adult bladder include leiomyosarcoma, fibrosarcoma and osteosarcoma. The radiologic findings of these sarcomas are nonspecific, and differentiation among them or from a large invasive transitional cell carcinoma is difficult [7]. Rhabdomyosarcomas are the most common pelvic malignancy in the pediatric group, which may arise in the bladder wall itself or from adjacent structures and secondarily involve the bladder. Large, cauliflower-like tumors with a locally invasive growth pattern and early hematogeneous and lymphatic metastasis are typical findings of rhabdomyosarcomas [16].

Primary bladder lymphoma is extremely rare, and the secondary involvement of systemic lymphoma is more common. Irregularities, thickening and nodular pattern of the bladder wall are nonspecific radiologic findings, and radiographically, they are indistinguishable from transitional cell carcinoma [7]. Nephrogenic adenoma is an unusual form of metaplasia of urothelial cells in response to injury or chronic inflammation. At ultrasound, these lesions appear as multiple small cystic or papillary nodules [17].

Secondary tumors of the bladder

The urinary bladder may be invaded directly by primary malignancies of the adjacent pelvic organs or metastasis from distant primary sites. Malignant tumors of the rectosigmoid colon, prostate, uterus and ovary may involve the urinary bladder by direct

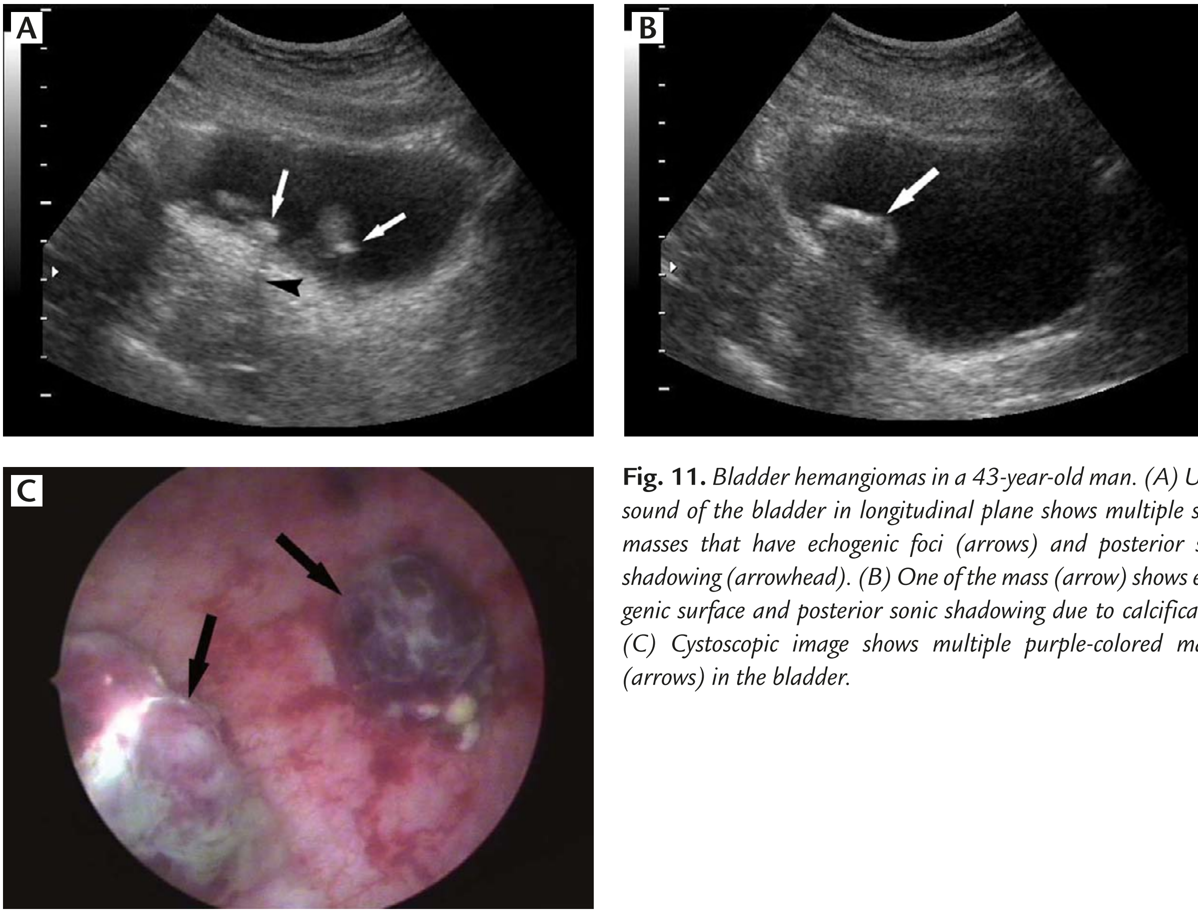


Fig. 11. *Bladder hemangiomas in a 43-year-old man. (A) Ultrasound of the bladder in longitudinal plane shows multiple small masses that have echogenic foci (arrows) and posterior sonic shadowing (arrowhead). (B) One of the mass (arrow) shows echogenic surface and posterior sonic shadowing due to calcification. (C) Cystoscopic image shows multiple purple-colored masses (arrows) in the bladder.*

invasion. Carcinoma of the uterine cervix or uterine corpus is the most common cause of direct bladder invasion in women, whereas carcinoma of the rectosigmoid colon is the most common cause in men [18,19]. Ultrasound shows irregularity or ill-demarcated mass in the wall of the bladder continuous with the mass in the primary site. These findings may vary with the depth of invasion of the vesical wall. These findings are not specific for neoplastic invasion, as the extension of inflammatory conditions can show identical findings.

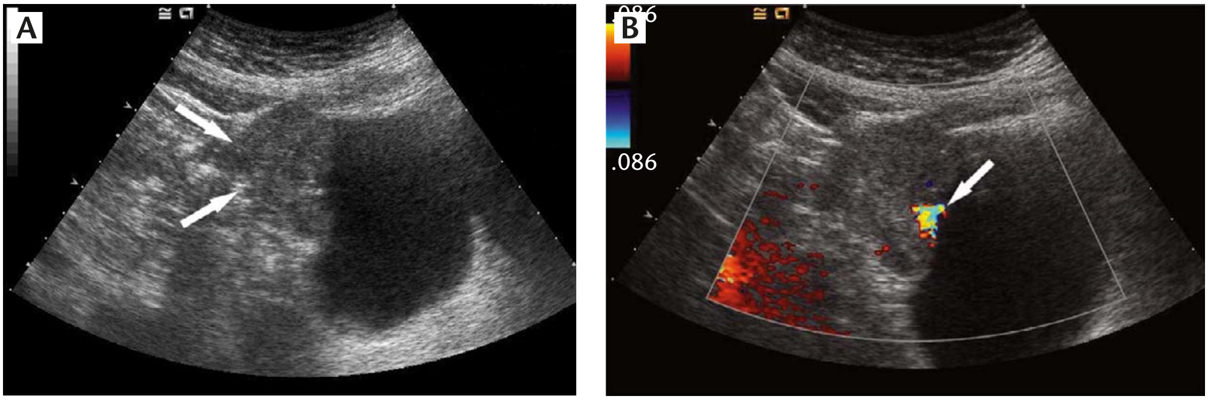
Bladder metastasis are rare and mostly found in advanced stages with peritoneal seeding. Most common primary sites are stomach, breast, lung and malignant melanoma. Metastatic tumors of the bladder appear as either polypoid lesions, similar to typical transitional cell carcinomas, or flat infiltrative lesions [20]. CDUS shows vascularity of the metastatic tumors, which are usually similar to the vascularity of the primary tumor [21].

Urachal carcinoma

About one-third of bladder adenocarcinomas are urachal carcinomas, most commonly mucinous adenocarcinomas. Psammomatous calcifications are common. Ultrasound shows a solid tumor in the midline anterior aspect of the bladder with wedge-shaped extravesical extension in the perivesical space toward the umbilicus (Fig. 12). Infected urachal remnant may show similar ultrasound findings [22,23]. Other urachal anomalies, such as urachal cyst or diverticulum, can also be shown by ultrasound [22].

Bladder Stones

Bladder stones can be classified as migrant, primary idiopathic endemic and secondary stones. Secondary bladder stones are related to urinary stasis or foreign bodies. The causes of urinary stasis include



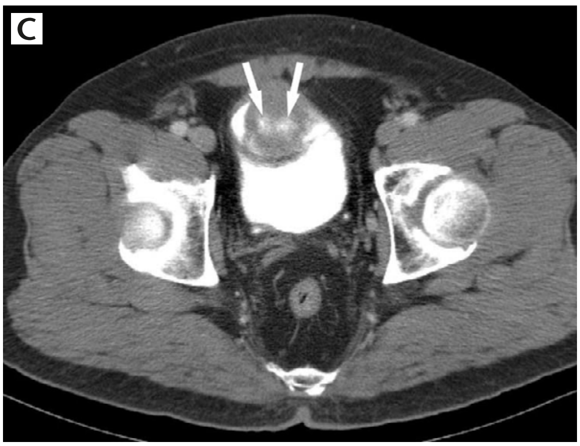


Fig. 12. *Mucinous adenocarcinoma of the urachus in a 67-year-old man. (A) Ultrasound of the bladder in longitudinal plane shows a solid mass in the anterior dome of the bladder with wedge-shaped bulging in the cranial direction (arrows). (B) Color Doppler ultrasound shows twinkling artifact (arrow) in the mass due to fine calcifications. (C) Contrast-enhanced computed tomography scan of the bladder shows calcification (arrows) in the mass.*

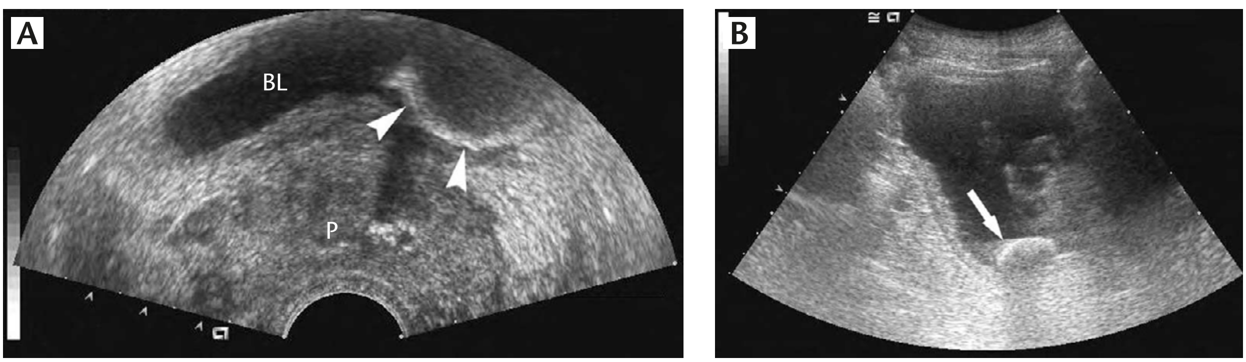


Fig. 13. *Bladder stone found incidentally at transrectal ultrasound that was done for evaluation of the prostate (P) in a 67-year-old man. (A) Transrectal ultrasound in transverse plane shows a curvilinear echogenicity (arrowheads) in the bladder (BL) due to a bladder stone. (B) Transabdominal ultrasound performed after bladder filling shows a large echogenic stone (arrow) with posterior sonic shadowing on the dependent portion of the bladder.*

bladder outlet obstruction such as benign prostatic hyperplasia, neurogenic bladder, urethral stricture, urethral or bladder diverticulum, or cystocele. This may be further complicated by superimposed infection [7]. Bladder stones may also form on a nonabsorbable suture, sponge, catheter or other foreign bodies that serve as a nidus for stone formation [24]. Bladder stones are well demonstrated with ultrasound by their characteristic echogenicity, posterior acoustic shadowing, location in the dependent portion, and movability with changes of patient's position. Sometimes, bladder stones are found incidentally at transrectal ultrasound, usually in patients with benign prostatic hyperplasia (Fig. 13).

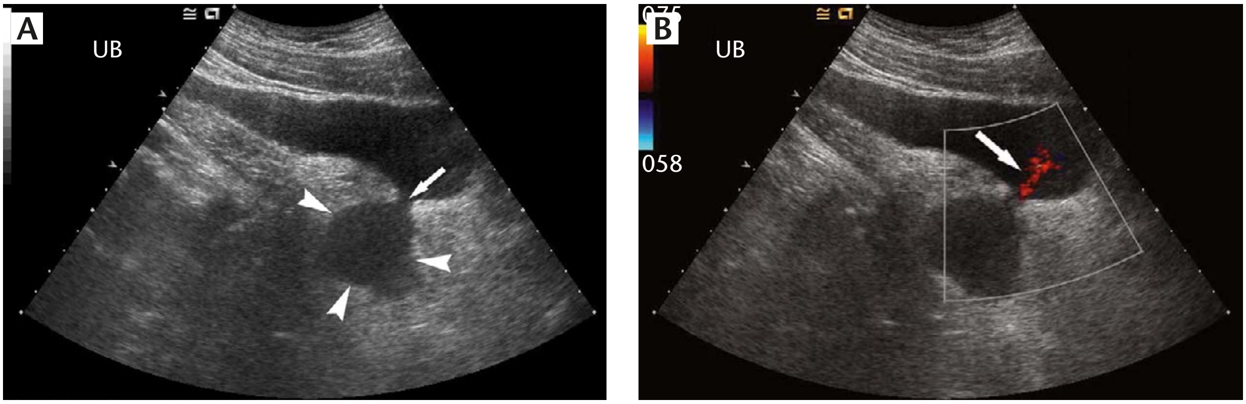


Fig. 14. *Bladder diverticulum in a 55-year-old man. (A) Longitudinal ultrasound of the bladder in left parasagittal plane shows a round diverticulum (arrowheads) connecting the bladder through a narrow neck (arrow). (B) Color Doppler ultrasound performed with Valsalva maneuver shows flow of urine (arrow) from the diverticulum to the bladder lumen. UB = urinary bladder.*

Bladder Diverticulum

Bladder diverticulum is a protrusion of the bladder mucosa through a focal weakness of the detrusor muscle, which is connected to the bladder lumen by a neck. Congenital bladder diverticula are rare and usually single, and the majority is located paraureterally along the posterolateral margin of the bladder. Acquired diverticula are often multiple and result from the chronically raised intravesical pressure in association with anatomical or neuropathic bladder outflow obstruction. Small outpouchings between the hypertrophied muscle bundles are called cellules or saccules. Although its distinction is somewhat arbitrary and subjective, it is convenient to consider cellules, saccules and diverticula, in that order, as increasingly severe manifestations of a chronically raised intravesical pressure. A wide-necked diverticulum empties readily when the bladder empties. A narrow-necked diverticulum empties slowly as the bladder empties and will, therefore, more likely have residual urine and urinary stasis. Retention of urine in the diverticula results in infection and stone formation [7].

Ultrasound easily shows diverticular cavity and neck (Fig. 14). When the bladder diverticulum has a narrow neck, it may be difficult to show communication with the bladder lumen, and then differentiation from other perivesical cystic lesions may also be difficult. These lesions to be differentiated from a narrow-neck diverticulum include seminal vesicle cyst, peritoneal inclusion cyst, mesenteric cyst, duplication cyst of bowel and Meckel's diverticulum [25,26]. Transrectal ultrasound may be better than transabdominal ultrasound in showing diverticular neck (Fig. 15). CDUS may be helpful in the differentiation by showing to-and-fro motion of urine flow across the diverticular neck (Fig. 14). This urine flow is better demonstrated by applying Valsalva maneuver. The diagnosis of bladder diverticulum may be facilitated also by ultrasound scanning at various degrees of bladder filling [26].

Tumors may occur in the diverticulum, which is shown as solid mass in a cystic lesion, by the ultrasound. CDUS may be helpful in differentiating tumor from a blood clot in the diverticulum [27]. The diverticular tumor, which is demonstrable at ultrasound, may not be demonstrated by cystoscopy if the diverticular neck is narrow. Diverticular cancer tends to invade perivesical tissue earlier because of lack of a muscle layer [11].

Ureterocele

Ureterocele is a congenital anomaly where intramural portion of the ureter shows fusiform dilatation. Simple ureterocele is an anomaly without clinical significance. Ectopic ureterocele, which is usually found in an upper moiety ureter in duplication

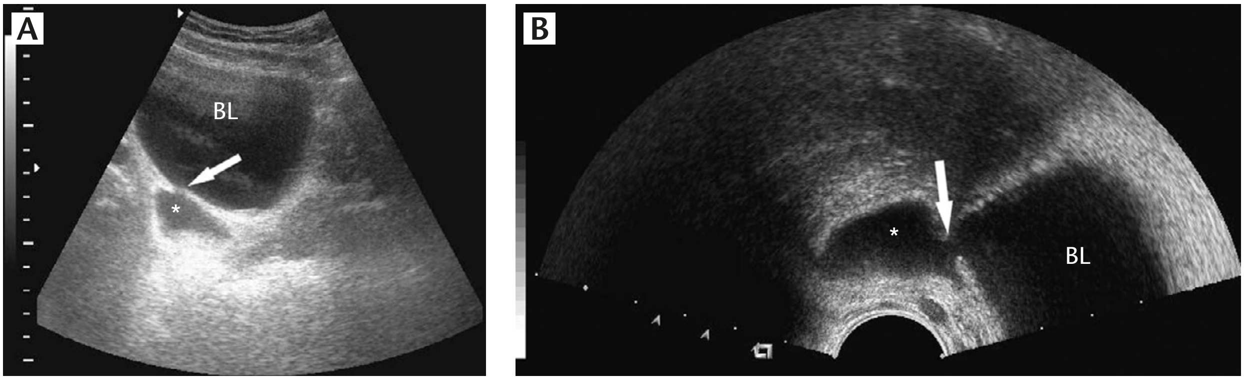
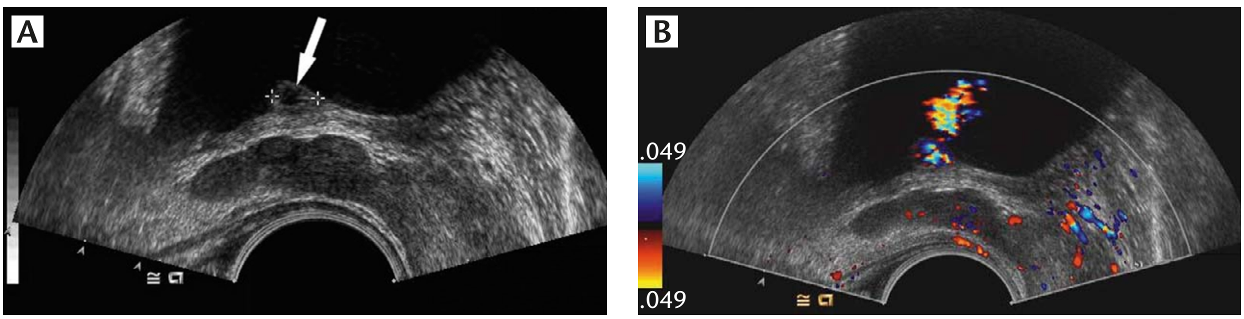


Fig. 15. *Bladder diverticulum in a 69-year-old man. (A) Transabdominal ultrasound in the transverse plane shows a cystic lesion (asterisk) in the right pelvic cavity posterior to the bladder (BL). There is a suspicious connection (arrow) between the bladder and the cystic lesion. (B) Transrectal ultrasound clearly shows that the cystic lesion (asterisk) is connected to the BL through a narrow neck (arrow).*



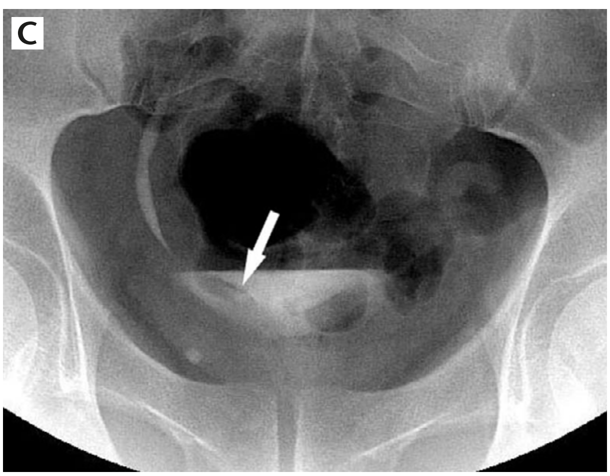


Fig. 16. *Simple ureterocele in a 46-year-old man. (A) Transrectal ultrasound in the oblique plane shows a small, thick-walled cystic lesion (arrow) in the right ureterovesical junction area. (B) Color Doppler ultrasound shows jetting of urine from the cystic lesion. (C) Intravenous urogram shows an ureterocele (arrow) in the right ureter.*

anomaly, is often associated with severe obstruction. Transabdominal ultrasound can show cystic lesion at the ureterovesical junction, but transrectal ultrasound more clearly shows the lesion. Ureteral orifice may be identified by urine jet using CDUS (Fig. 16).

Cystitis

Ultrasound shows focal or diffuse thickening of the bladder wall in cystitis of various causes. Often, it is difficult to differentiate between cystitis and tumor on the basis of ultrasound findings. Cystitis cystica,

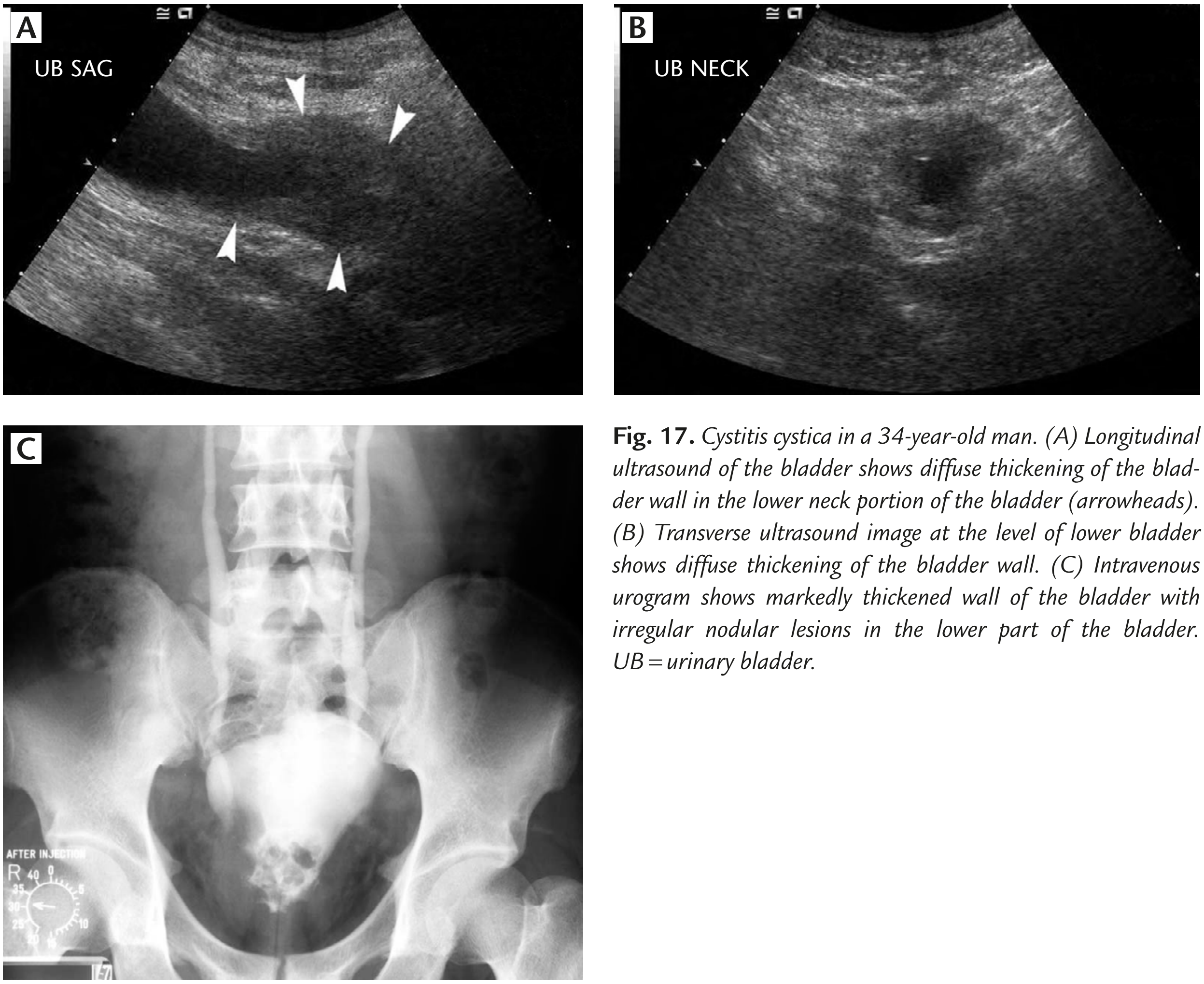


Fig. 17. *Cystitis cystica in a 34-year-old man. (A) Longitudinal ultrasound of the bladder shows diffuse thickening of the bladder wall in the lower neck portion of the bladder (arrowheads). (B) Transverse ultrasound image at the level of lower bladder shows diffuse thickening of the bladder wall. (C) Intravenous urogram shows markedly thickened wall of the bladder with irregular nodular lesions in the lower part of the bladder. UB = urinary bladder.*

eosinophilic cystitis and condyloma acuminatum may closely mimic a bladder tumor [28,29] (Fig. 17). Hemorrhagic cystitis often occurs following pelvic irradiation, where ultrasound shows hypervascularity in the thickened wall and clot in the lumen [30]. Emphysematous cystitis is an uncommon complication of urinary tract infection, and ultrasound shows intramural echogenic foci accompanying reverberation artifact caused by intramural gas [31]. Tuberculous cystitis develops in about one-third of the patients with tuberculosis of the upper urinary tract. In the early destructive phase of the disease, ultrasound shows mucosal thickening with irregular margin due to coalescent mucosal tubercles and ulcerations (Fig. 18). In the late stage of the disease, ultrasound shows contracted bladder with thickened wall due to transmural fibrosis [32].

Fistulas Involving Urinary Bladder

Urinary bladder may be involved by fistulous communication with adjacent organs, such as vagina, uterus or bowel. The etiology of these fistulas includes obstetric complications, pelvic malignancy, radiation therapy, inflammatory bowel disease, or iatrogenic or traumatic causes [33]. Vesicouterine fistula usually occurs after lower-segment cesarean section, causing urinary incontinence or menouria. Although fistula itself is difficult to be shown with ultrasound, the diagnosis can be suggested by showing double echogenic lines between the endometrium and bladder [34] (Fig. 19). However, this ultrasound finding is difficult to differentiate from the findings in a noncomplicated cesarean scar [35].

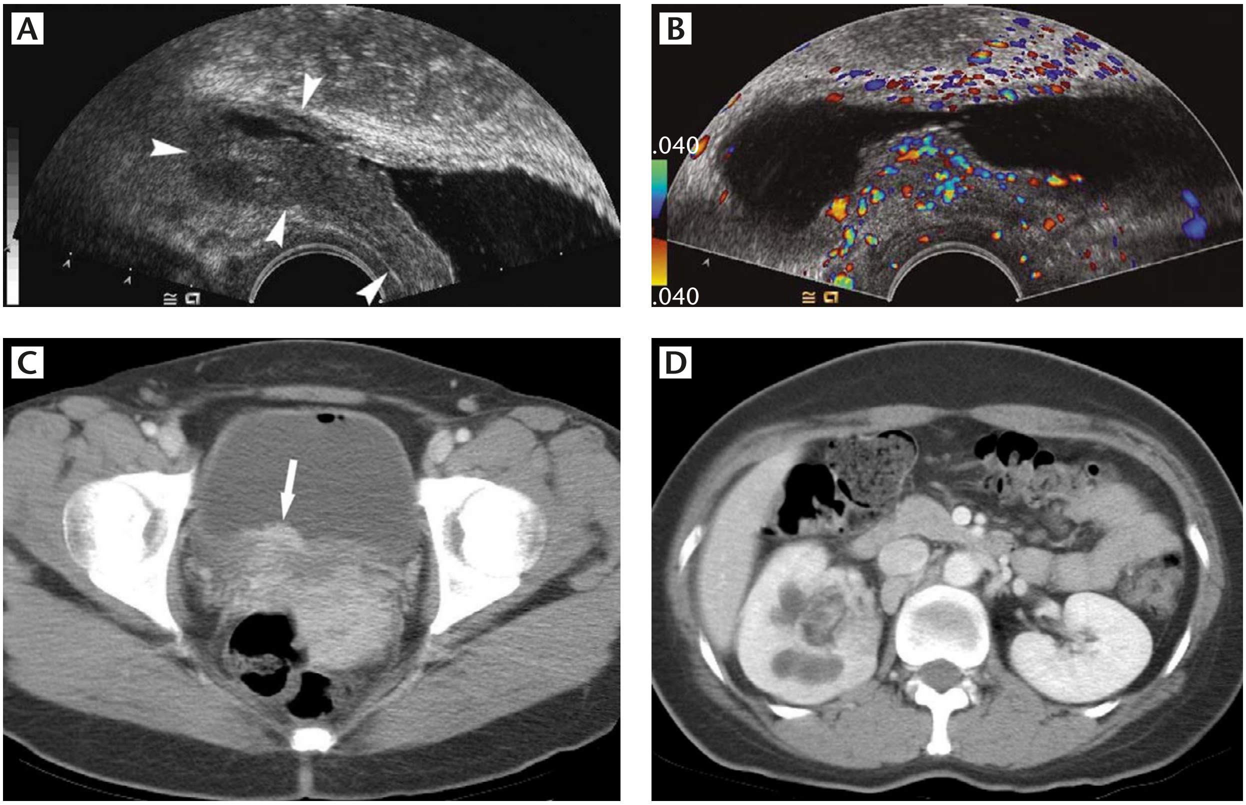


Fig. 18. *Tuberculosis of the right kidney and bladder in a 39-year-old woman. (A) Transvaginal ultrasound in the oblique plane shows irregular thickening of the wall in the right aspect of the bladder (arrowheads). (B) Color Doppler ultrasound in the transverse plane shows increased vascularity of the lesion. (C) Contrast-enhanced computed tomography (CT) scan shows thickening of the bladder wall in the right posterior aspect of the bladder (arrow). (D) Contrast-enhanced CT scan of the kidney shows dilated calyces and contracted renal pelvis in the right kidney due to tuberculosis.*

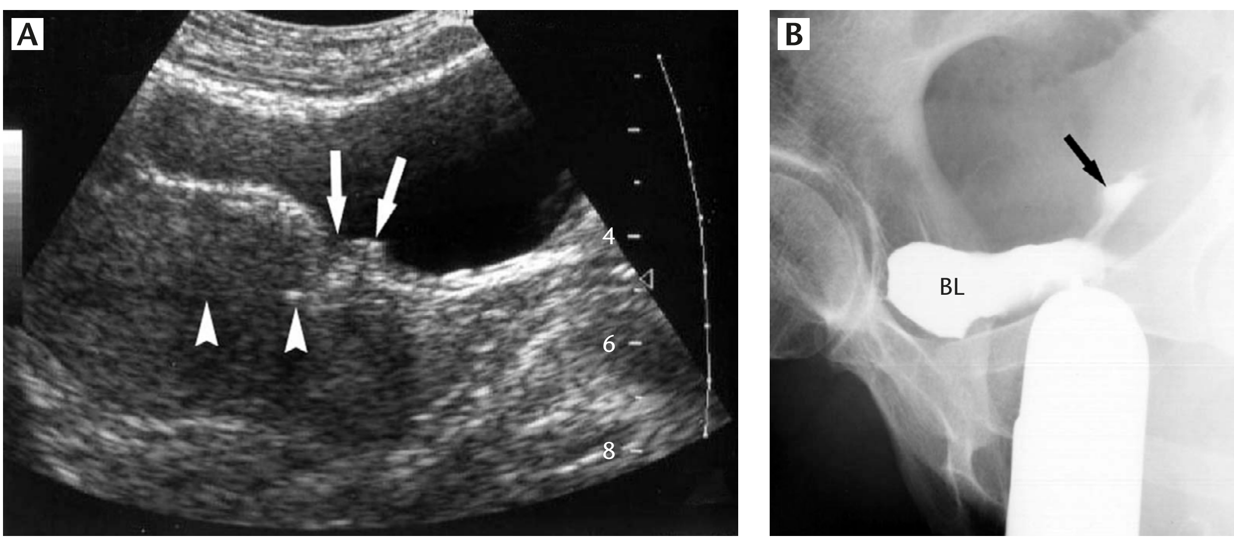


Fig. 19. *Vesicouterine fistula after cesarean section in a 27-year-old woman who complained of cyclic hematuria after surgery. (A) Longitudinal ultrasound of the uterus shows suspicious defect (arrow) in the lower anterior uterus, which appears continuous with the echogenic endometrium (arrowheads). (B) Hysterosalpingography opacified both uterus (arrow) and bladder (BL) due to vesicouterine fistula.*

Foreign Bodies in the Bladder

A wide variety of foreign bodies found in the bladder has been reported. Some of them, such as fractured catheters, are introduced iatrogenically, but the majority of them are objects self-introduced through the urethra in patients with abnormal psyche. Radiopaque foreign bodies can be easily identified at plain radiographs, but radiolucent ones are difficult to find. Ultrasound usually shows the foreign bodies as high-reflecting lesions moving in the bladder [36].

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