Pictorial essay

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Multiparametric ultrasound imaging of the urinary bladder beyond urine volume measurements. A pictorial essay.

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Abstract

Ultrasound of the urinary bladder detects diverse and complex pathology. This manuscript deals with various bladder diseases imaged with multiparametric ultrasound, including contrast enhanced ultrasound.

Keywords: urinary bladder; ultrasound; CEUS

Introduction

The urinary bladder is routinely imaged with ultrasound (US). Some pathologies are diagnosed with standard B-mode US, while others are complex, requiring multiparametric US, including contrast enhanced US (CEUS), computed tomography (CT) or magnetic resonance imaging (MRI).

Indications for bladder US

1. Bladder volume, residual urine volume post micturition

Most devices enable automatic measurements using the standard Poston formula [1]. After micturition, the bladder is re-scanned and residual urine volume is measured. Significantly increased residual urine volume suggests urinary retention.

2. Diverticula

Diverticula are protrusions of bladder urothelium and mucosa via the muscularis propria, due to defects between detrusor muscle fibers. Thus, parts of bladder lumen protrude outwards (fig 1).

Upon chronic obstruction, muscle bladder wall bundles stretch, acquiring a coarse interwoven texture ("trabeculation"). In patients overcoming obstruction during micturition, bladder pressure increases [2], forming small cellules which infiltrate through the wall, forming diverticula.

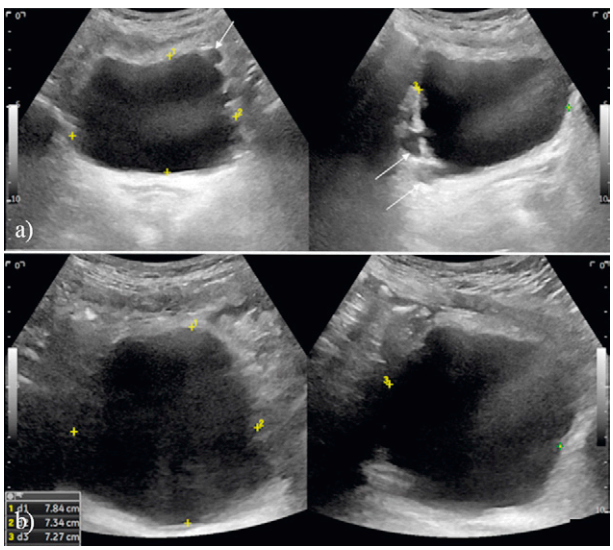


Fig 1. Patient with multiple sclerosis shows trabeculated bladder and diverticula (arrows in a). Bladder volume is pre-voiding 230 mL and post-voiding 220 mL (b), due to urinary retention.

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US depicts diverticula as anechoic lesions outside of the bladder lumen. If pedunculated, an isthmus connects the diverticulum to the bladder. A large diverticulum is difficult to differentiate from the lumen (fig 2).

3. Bladder calculi

Bladder stones form within the bladder or migrate from the kidneys. On US stones present as echogenic lesions with posterior shadow [3] (fig 3). Bladder tumors are differentiated from stones by changing the patient's position: stones move, while masses do not.

4. Tumors

On US, bladder tumors appear as echogenic wall-adherent masses, occasionally with calcifications. Tumors may warrant differentiation from debris. When the patient's position changes, masses are immobile, while debris and hemorrhagic material can change position. Color Doppler and techniques such as Microvascular Imaging (MVI) show perfusion in tumors, while debris shows no perfusion (fig 4). CEUS better differentiates blood clot without contrast uptake from enhancing tumor masses [4] (fig 5, fig 6).

In patients with a post cystectomy due to bladder malignancies, the urine is collected in a surgically created external pouch or in an ileal conduit (fig 7).

5. Benign prostatic hyperplasia (BPH)

BPH is common in elderly men. The prostate is enlarged (volume over 30 mL). Residual urine volume post micturition is increased, and the bladder wall appears hy-

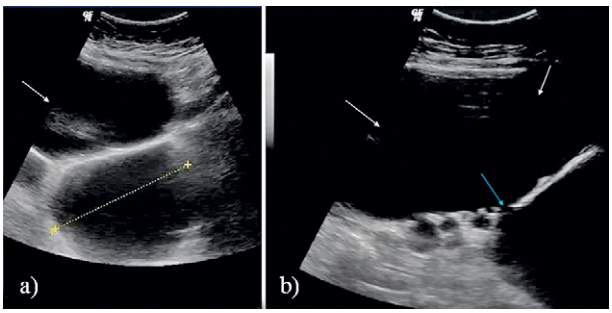


Fig 2. Large bladder diverticula are seen on B-mode US. Due to their size, differentiation from the actual bladder lumen (white arrows in a, b) remains challenging. Communicating points (blue arrow in b) between lumen and diverticula help to differentiate bladder lumen from diverticula.

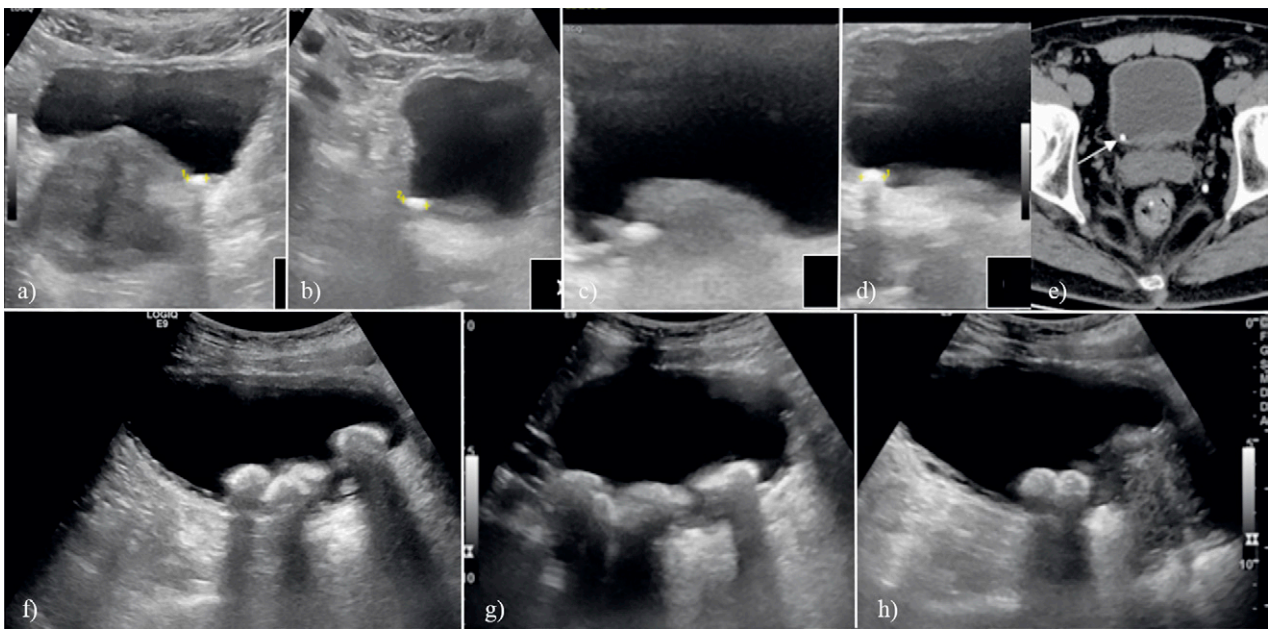


Fig 3. Two patients with bladder stones. Patient 1: Stones in the bladder move with patient position changing: a) supine, b) right decubitus, c) left decubitus, d) supine; e) CT confirms the stones (arrow). Patient 2: Stones in the bladder move while changing patient positioning (f, g, h).

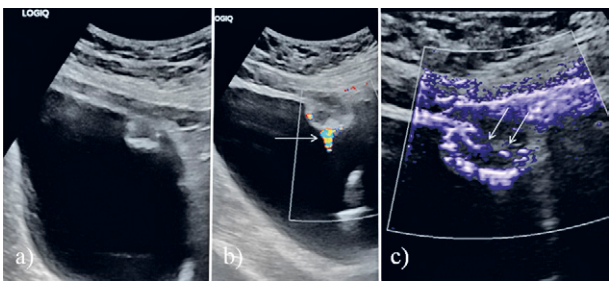


Fig 4. Incidental finding of a bladder TCC. B-mode US (a) shows a papillary projection. Color Doppler (b) shows no perfusion. A twinkling artifact (arrow) is caused by denser lesion parts. MVI technique (c) visualizes internal linear blood flow signals delineating blood vessels (arrows), suggesting a tumor. There are also artifactual signals at the lesion's margin.

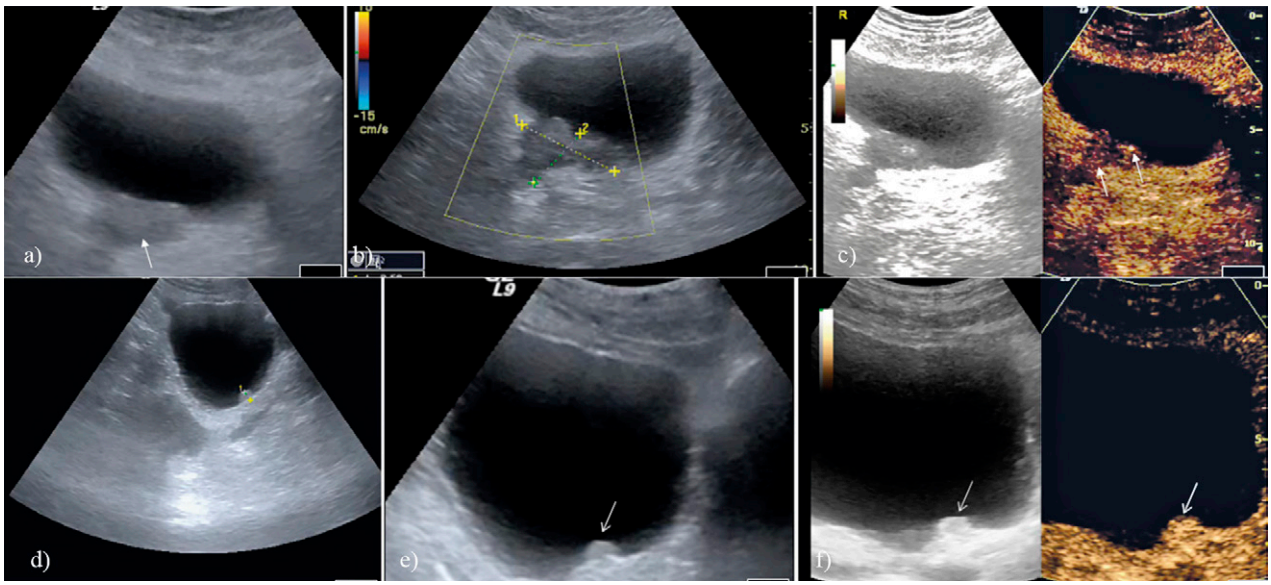


Fig 5. Two different patients with bladder tumors. Patient 1: an echogenic lesion invades a diverticulum on B-mode US (arrow in a), with no perfusion on color Doppler US (between calipers in b). On CEUS the lesion enhances (arrows in c). Patient 2: a 6 mm echogenic lesion is noted on B-mode US (between calipers in d, arrow in e). On CEUS the lesion enhances (arrow in f).

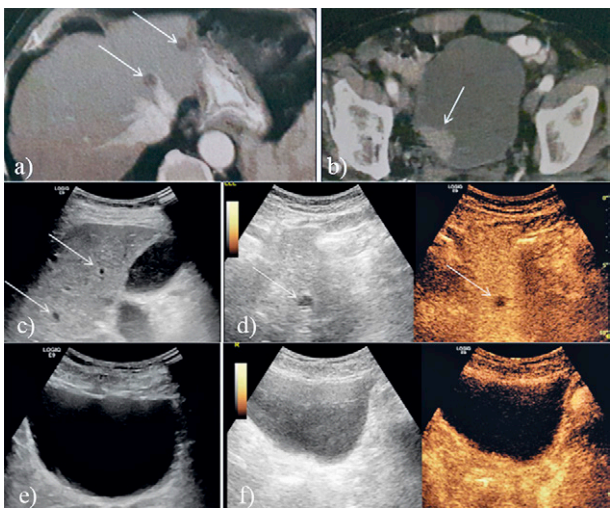
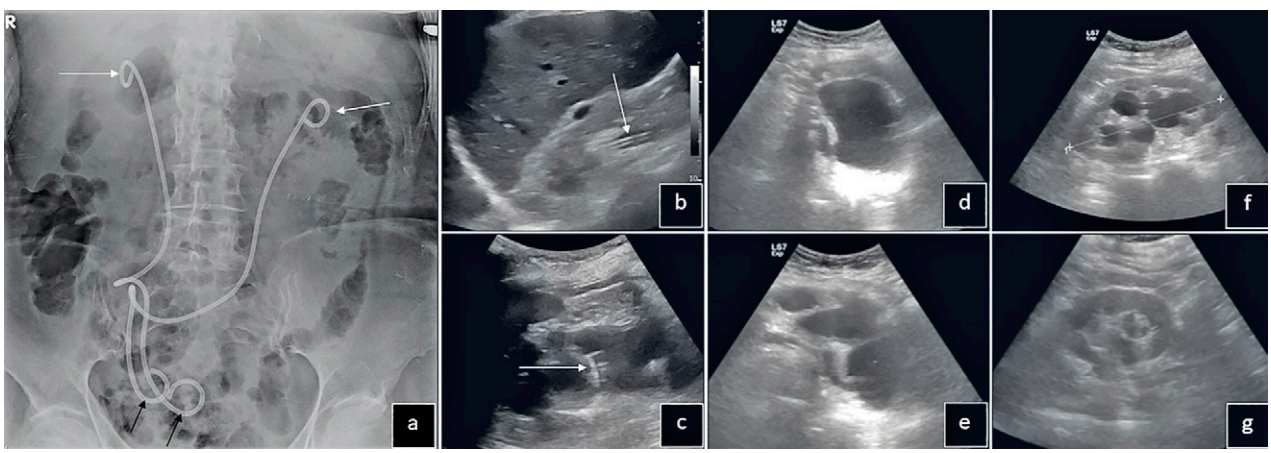


Fig 6. A patient with known bladder neoplasia undergoes CECT (a, b), demonstrating hypoattenuating hepatic cysts (arrows in a). The bladder mass is noted (arrow in b). After 8 months of treatment, the liver cysts are again seen on follow-up B-mode US (arrows in c) and confirmed on CEUS (arrows in d). No residual mass is seen inside the bladder on B-mode US (e) and on CEUS (f).

Fig 7. Two different patients with bladder removal. Patient 1: Urine collects in an external pouch. Double J catheters bilaterally are evident on radiograph (arrows in a). The distal ends terminate within the pouch. Proximal Cope loops are seen on US in the right (arrow in b) and left (arrow in c) renal collecting system. Patient 2: The bladder is replaced by an ileal conduit (d, e). The central renal collecting systems of the right (f) and the left (g) kidney show hydronephrosis.



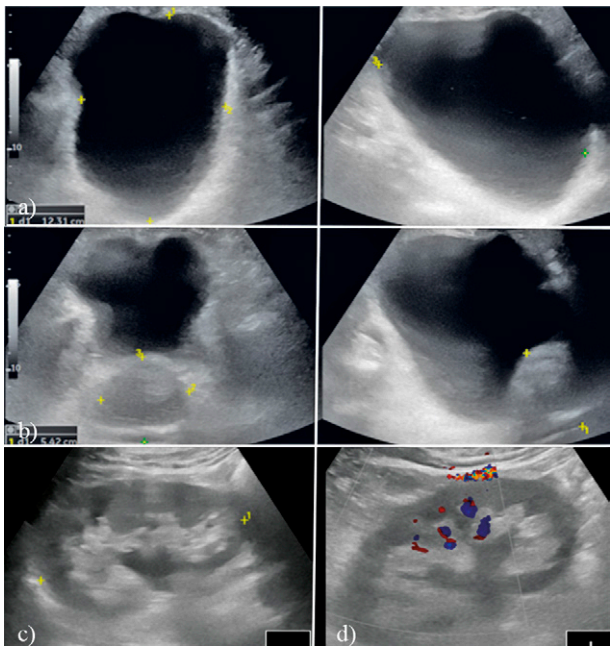


Fig 8. The bladder is distended (a: urine volume almost 700 cc) secondary to prostatic gland enlargement (b: volume of 73 cc), with hydroureteronephrosis of right (c) and left (d) renal collecting systems.

pertrophic and trabeculated secondary to bladder outlet obstruction (fig 8) [5].

6. Debris and blood clots

Debris represents mobile, echogenic particles in urine within the pelvicalyceal system, ureters or bladder [6]. It appears on US as small dependent echogenic particles, mobile when changing patient positions. Large debris quantities may appear layered (fig 9). CEUS differentiates enhancing tumors from adjacent hemorrhagic debris/blood clot or puss (fig 10, fig 11).

7. Fistulae

Fistulae are abnormal communications between two epithelialised surfaces. In the bladder, fistulae form between bladder and vagina/uterine cavity (vesicovaginal fistulae), gastrointestinal tract (fig 12) (colovesical, ileovesical, rectovesical fistulae), urethra, skin and abdominal wall.

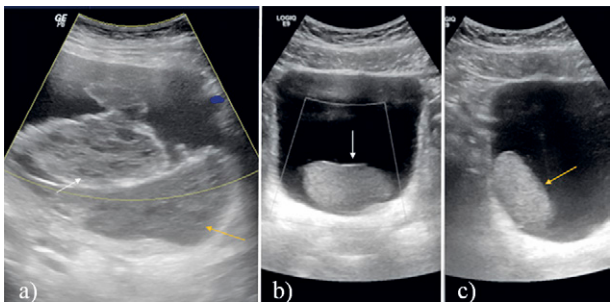


Fig 9. Two different patients with bladder debris. Patient 1: Debris is chronic (a) since two separate layers have formed (white and yellow arrows). Patient 2: Debris has a mass-like configuration (b, c), though it is mobile with altered patient positions (white arrow in supine position, yellow arrow in right decubitus position.

8. Cystitis

Sonographic findings of cystitis include [7] bladder wall hypertrophy (fig 13), mucosal irregularity, debris, periserosal edema, bladder wall calcification. Underlying findings include tumor, foreign body, diverticulum. In emphysematous cystitis, US demonstrates echogenic free air within the bladder wall and wall thickening.

9. Trauma

On CEUS a hematoma adjacent to the bladder appears as a biconvex non-enhancing area (fig 14). CEUS can also be performed instilling diluted contrast agent through the catheter (retrograde transurethral CEUS) (fig 15) [8].

10. Ureterocele

Ureteroceles are congenital saccular dilatations of the distal ureter, herniating inside the bladder lumen due to abnormal ureterovesical junction (UVJ). On US ureteroceles appear as cystic lesions of dilated distal ureter (fig

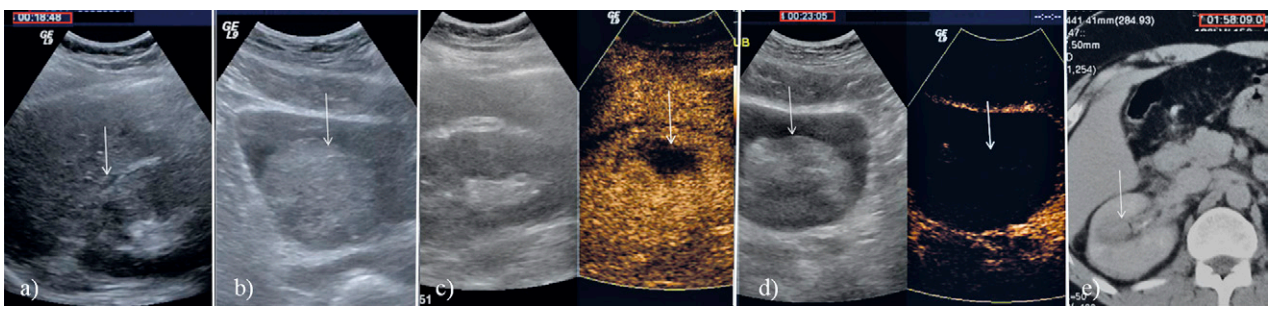


Fig 10. A motorcycle accident victim undergoes B-mode US shortly after midnight (time reads 00:18 in red box in a). The right kidney is heterogenous with small fluid collection in Morison's pouch (arrow in a). Echogenic material is seen within the bladder (arrow in b). CEUS reveals right kidney laceration (arrow in c). The bladder hemorrhagic content does not enhance (arrows in d). The CEUS examination is completed within 5 minutes by 00:23 (time in red box in d). Right kidney trauma is confirmed on CECT (arrow in e) much later (time in red box in e reads 01:58).

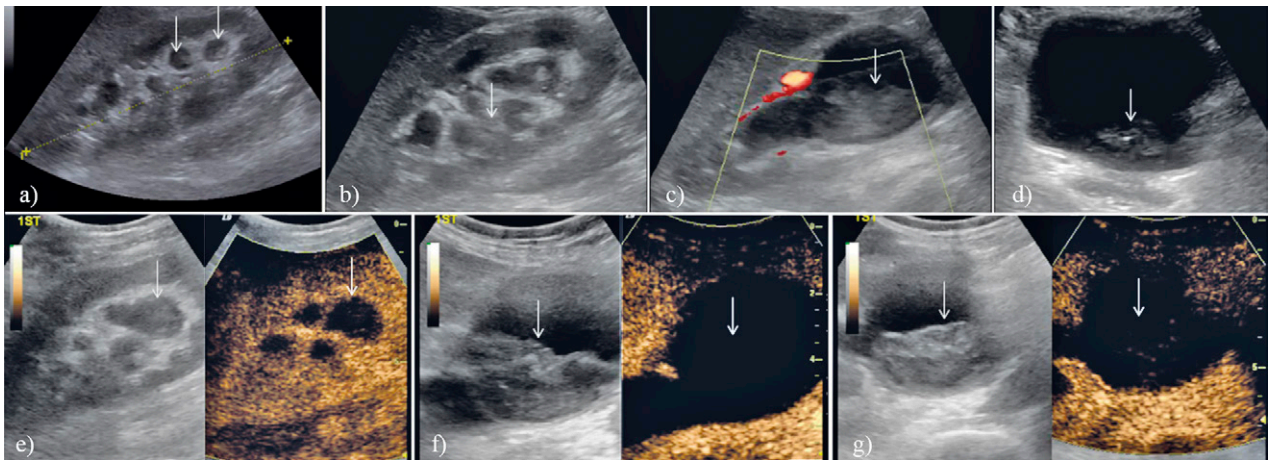


Fig 11. The right kidney is enlarged due to pyelonephritis with echogenic pus (arrows) in its calyces (a) and renal pelvis (b, c) on B-mode US (a, b) and power Doppler US (c). Echogenic material is also present in the bladder (arrow in d). CEUS shows non-enhancement of the echogenic infectious material in the right renal collecting system (arrows in e), renal pelvis (f) and urinary bladder (g).

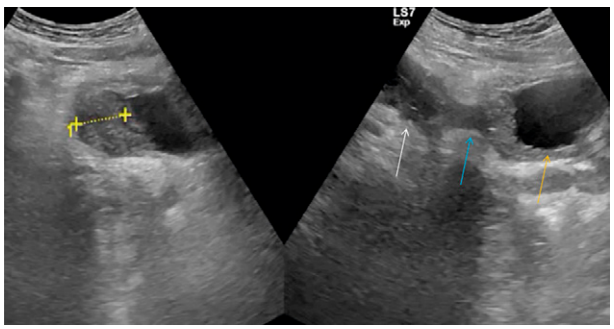


Fig 12. Patient with Crohn's diseases shows a fistula (blue arrow) between the bowel loop (white arrow) and bladder (yellow arrow). The bladder wall is thickened (between calipers).

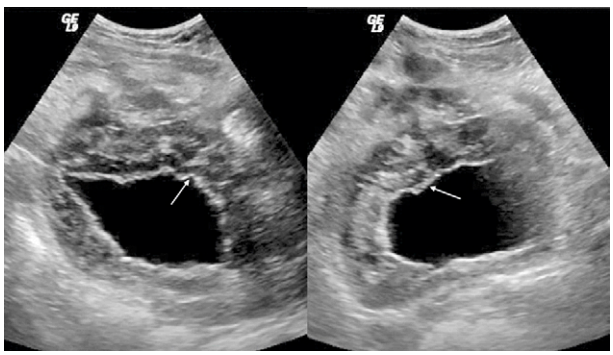


Fig 13. Homogeneous thickening of the bladder wall (arrows) is noted on B-mode US secondary to cystitis.

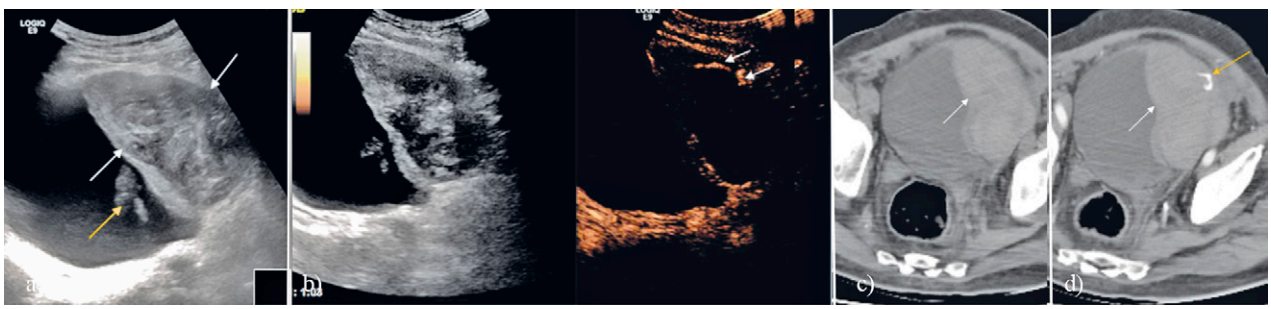


Fig 14. On B-mode US (a) a biconvex hematoma (between white arrows) is seen abutting the bladder, with hemorrhagic material in the lumen (yellow arrow). CEUS (b) detects ongoing hemorrhage (white arrows). CT before (c) and after (d) contrast administration confirms hematoma (white arrows in c, d) and contrast arterial extravasation (yellow arrow in d).

16), projecting into the bladder ("cyst within a cyst" [9]). CEUS and CECT demonstrate a rounded filling defect in the bladder at the ureteral insertion site ("cobra head" sign).

11. Further pathologies of distal ureters

Normal ureters are not visualized by US. When dilated, the terminal third may be seen [2]. The UVJ is the narrowest ureter part, a common location for stone compaction and ureter dilatation (fig 17). Tumors of the UVJ also cause ipsilateral ureter dilatation. Any pathology compromising bladder voiding may cause distal ureter dilatation (fig 18).

12. Foreign objects

Radiopaque foreign bodies are noted on radiographs, but radiolucent ones are not. Regardless of radiolucency, most foreign objects are identifiable on US as echogenic

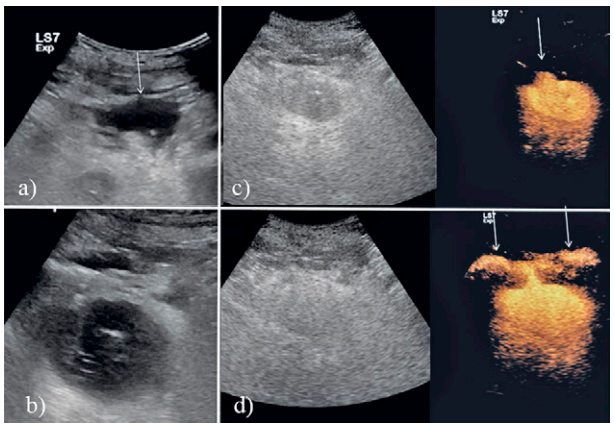


Fig 15. The decompressed bladder reveals focal wall integrity loss due to rupture (arrow in a). The bladder is filled through a catheter with sterile normal saline (b). Diluted contrast is injected through that catheter. CEUS depicts bladder rupture as contrast extravasation (arrow in c) and urinoma (arrows in d).

mobile structures within the bladder [10]. Erection-supportive medical devices may appear as anechoic findings next to the bladder and should be differentiated from diverticula (fig 19).

Conclusion

US of the urinary bladder is performed routinely. Various entities may be detected using US. In many patients,

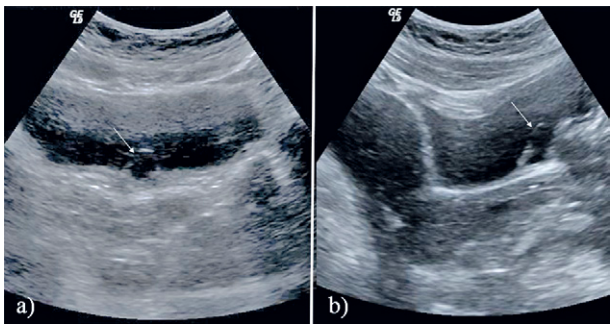


Fig 16. A hypoechoic lesion with a thin wall (arrows) is seen on the coronal (a) and sagittal (b) B-mode US, consistent with ureterocele.

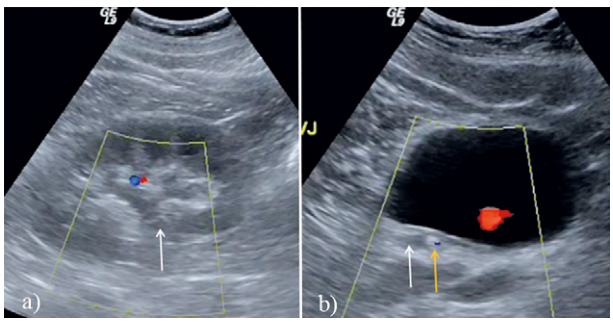


Fig 17. The right kidney collecting system shows dilatation (arrow in a) extending to the level of the UVJ (white arrow in b). Dilatation is caused by a stone impacted in the right UVJ (yellow arrow in b).

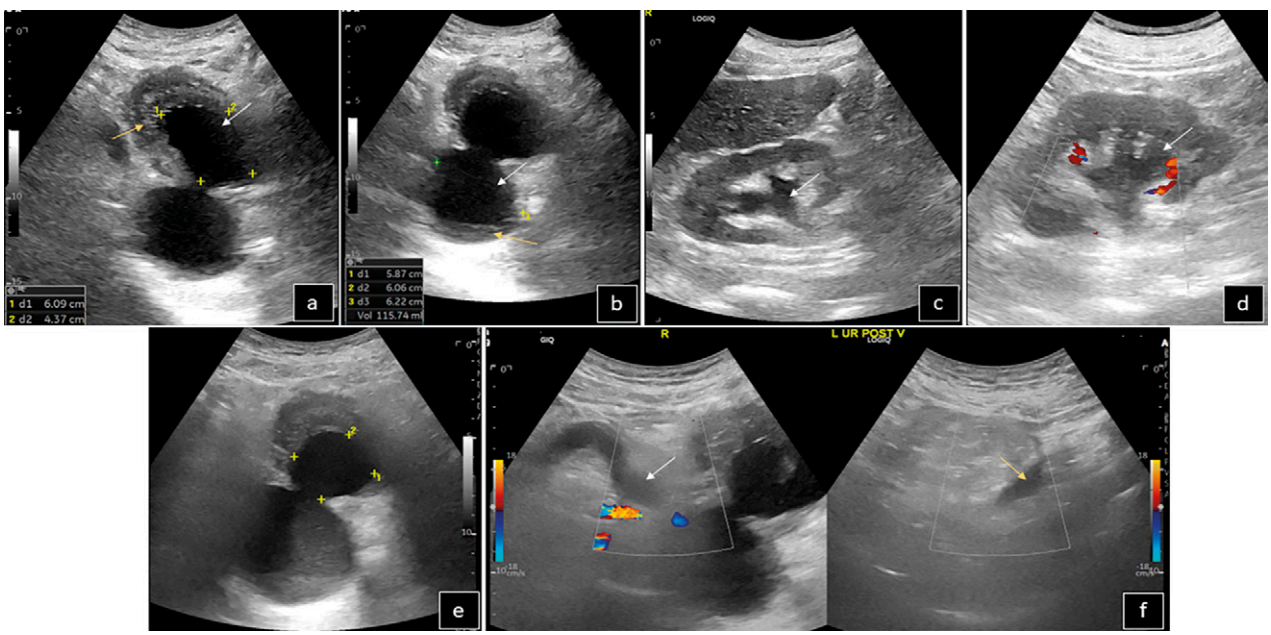


Fig 18. Bladder architecture is altered - the true lumen (white arrow in a), with a volume of 65 cc and thickened wall (yellow arrow in a) communicates with a diverticulum with a volume of 115 cc (white arrow in b) and debris (yellow arrow in b). Bilateral hydronephrosis (arrows in c, right kidney and d, left kidney) is seen. Post micturition (e) the true urinary bladder lumen shows only partial emptying (post void volume 30 cc). The diverticulum retains a significant amount of urine (post void volume 85 cc). Post voiding hydroureteronephrosis remains unchanged (white arrow in f: right ureter, yellow arrow: left ureter).

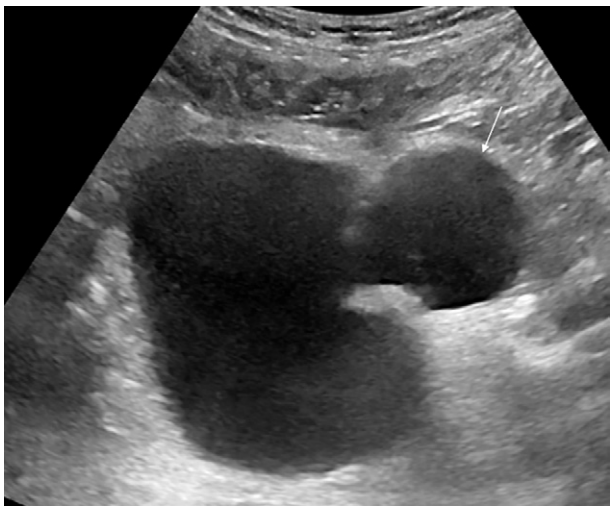


Fig 19. A medical erection-helping device is noted next to the bladder (arrow). History is needed to differentiate this from a diverticulum on US.

baseline, unenhanced US is sufficient for diagnosis. CEUS can elucidate complex findings.

Conflict of interest: none

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