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# Essentials of Interventional Nephrology






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CHAPTER 6

# Renal Ultrasound

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## INTRODUCTION

Ultrasonography is an expanding field with increasing clinical practice globally. It does not use any ionizing radiation and is noninvasive, therefore it is a safe modality to evaluate the kidneys and urinary tract. Point-of-care ultrasound allows nephrologists to evaluate patients at the bedside, forming an extension of physical examination. This allows for real-time examination for a wide range of indications including abdominal or flank pain, renal dysfunction, detection and follow-up of masses in the urinary tract, renal stones as well as other pathologies described in this chapter.

## EQUIPMENT

A low-frequency 3–6 MHz curvilinear transducer.

## PREPARATION FOR KIDNEY ULTRASOUND SCANNING

- Kidney ultrasound is typically performed with the patient in the lateral decubitus position. In emergency settings, the supine position is often preferred. For those undergoing ultrasound as part of a native renal biopsy, the prone position is commonly used.
- Enhancing the visibility of the kidneys can often be achieved by having the patient raise their arms above their head and take a deep breath in.
- To obtain optimal views of the collecting system and bladder, it is recommended that the patient consumes approximately 500 mL of fluid 1 hour before the scan, ensuring that they avoid micturition. If a urinary catheter is present, it should be clamped for 1–2 hours prior to scanning.

## LOCATING THE KIDNEYS

The kidneys are located deep to the posterolateral lower rib cage within the paravertebral gutters. They sit between the levels of T12 and L4 vertebrae. The superior poles of the kidneys are tilted slightly posterior and medial with respect to the inferior poles.

The right kidney lies inferior and posterior to the right lobe of the liver. It is covered anteriorly by the liver and inferiorly by the right colic flexure and duodenum. The most effective approach for scanning the right kidney is through the intercostal spaces from the posterolateral side or mid-axillary line, utilizing the liver as an acoustic window.

The left kidney lies posterior and inferior to the spleen, with the stomach overlapping the front of the upper pole. Its lower half is covered by the descending colon and left colonic flexure, which passes around its anterior surface. Like the right, the left kidney is best scanned through a posterolateral approach using the intercostal spaces and spleen as an acoustic window. The left kidney is generally located higher and posterior compared to the right, making it more challenging to scan due to the intervening gas.

Start scanning both kidneys in longitudinal views. Once a clear image is acquired, fan the probe to cover the entire organ. Rotate the probe 90° to examine the kidney in the transverse plane, scanning from pole to pole. Both kidneys should be scanned routinely for comparison and to identify any anatomical variations.

### Abnormalities in Kidney Location

- *Renal agenesis:* One kidney is absent, while the contralateral kidney may be enlarged.
- *Ectopic kidneys:* One or both kidneys may be located outside the normal renal fossa, often in the pelvis, but they may be obscured by bowel gas.

### Renal Size

Kidneys can be measured in three dimensions: Length, width, and thickness **(Fig. 1)**. The longitudinal scan is

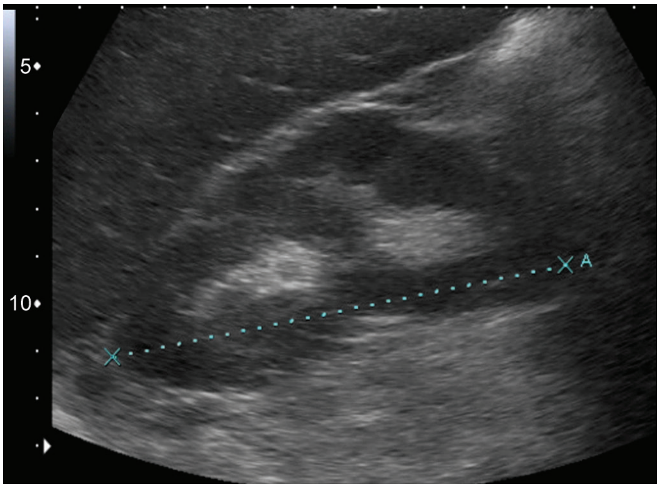


**Fig. 1:** Normal right kidney measuring 10.7 cm.

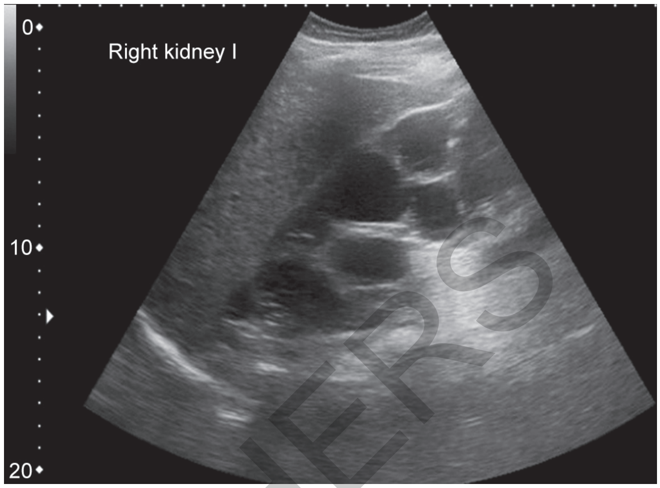


**Fig. 2:** Polycystic kidneys containing multiple hypoechoic cysts with no internal shadows.

ideal for measuring renal length. Freeze the image and measure the maximum length from pole to pole. For width and thickness, the transverse view is most effective.[1]

*Normal renal dimensions:*
- *Length:* 9–12 cm
- *Width:* 4–7 cm
- *Thickness:* 3–5 cm

### *Small Kidneys*

Causes of bilateral small kidneys include:
- Chronic renal diseases such as glomerulonephritis, renal artery stenosis, reflux nephropathy, and chronic pyelonephritis
- Aging
- Low body weight or height

### *Enlarged Kidneys*

Renal enlargement can be seen in conditions like acute glomerulonephritis, hydronephrosis, and amyloidosis. Renal masses or cysts, such as in polycystic kidney disease,[2] can also cause the kidneys to appear enlarged **(Fig. 2)**.

## APPEARANCE OF THE KIDNEYS ON ULTRASOUND

The kidneys are bean-shaped with a smooth surface. It is not uncommon for older patients to exhibit surface indentations. Pyelonephritis can also cause such indentations. The parenchyma of the left kidney often forms a bulge beneath the spleen's border, creating a "dromedary hump".

*Anatomical variants:*
- *Horseshoe kidney:* The two kidneys are connected at their lower poles by a parenchymal isthmus, forming a U-shape.
- *Duplication of the collecting system:* This developmental abnormality results in two ureters.
- *Extrarenal pelvis:* In about 10% of individuals, the renal pelvis lies outside the renal hilum. The renal pelvis is formed by the major calyces and the extrarenal pelvis can appear dilated, leading to a false impression of urinary obstruction.

### Renal Parenchyma and Sinus

*The kidneys consist of three main layers:* The cortex, the medulla (collectively referred to as the renal parenchyma), and the renal sinus. The kidneys and adrenal glands are encased in a dense fibrous capsule called Gerota's fascia. Just beneath this capsule is the cortex, which typically measures 5–7 mm in thickness and decreases with age. The columns of Bertini are projections of cortical tissue that extend into the medulla. These columns separate the 8–10 renal pyramids, which have a characteristic hypoechoic appearance on ultrasound. This is especially prominent in younger patients and can be mistaken for renal cysts.[3]

The apex of each renal pyramid forms a papilla, which excretes urine into a corresponding minor calyx. Several minor calyces converge to form the major calyces, which then merge to form the renal pelvis. The latter tapers through the renal hilum into the proximal ureter. The transition between the renal pelvis and ureter is the ureteropelvic junction (UPJ), which is a common site of obstruction from ureterolithiasis. This is typically at the level of the hilum, where blood vessels, lymphatics, and ureters pass through. Collectively, the minor and major calyces, intrarenal blood vessels, and surrounding fat tissue constitute the renal sinus, which is the hyperechoic central region of the kidney.

The collecting system and ureters are usually not visible on ultrasound unless hydronephrosis is present. The ureters descend across the psoas muscle, crossing the common iliac vessels at the pelvis brim and then anteriorly and medially to empty into the bladder via the ureterovesical junctions (UVJs) at the two superior corners of the trigone. In severe urinary retention, the distended bladder can extend to the level of the umbilicus.

## Circumscribed Lesions

- *Hyperechoic:*
  - *Angiomyolipomas:* These are benign tumors, round, homogeneous, well-circumscribed masses. They are typically within the renal parenchyma containing blood vessels, muscle tissue, and fat. They are usually solitary and asymptomatic, if multiple and bilateral can be associated with tuberous sclerosis.
  - Renal scars
  - Calcifications **(Fig. 3)**
- *Isoechoic:* Renal cell carcinoma (RCC)
- *Hypoechoic:*
  - Intracystic hemorrhage
  - Abscess: Appears with irregular margins and possible bright internal echoes
- *Echo-free: Simple cysts* **(Fig. 4)**: Smooth, thin-walled, round or oval-shaped cysts with posterior acoustic enhancement. These may be solitary or multiple. Cysts are classified by their location: Pararenal, cortical, or parapelvic. Cysts that have irregular borders, septations, calcifications, or heterogenous echo density should be referred for further evaluation.

## Polycystic Kidney Disease

Polycystic kidney disease is a hereditary condition with multiple cysts of various sizes, with compression and thinning of the renal parenchyma, leading to the eventual replacement of renal parenchyma by cysts.

## Renal Cancer

Renal cancer has a varied appearance on ultrasound. Any unexplained mass or disruption of the renal architecture should be considered for referral for further imaging. Smaller RCCs can be hyperechoic and may be mistaken with angiomyolipomas; however, they tend to be less well defined. Larger RCCs may show cystic degeneration, calcification, and disorganized blood flow on color Doppler.

## Intrarenal Hematomas

Intrarenal hematomas can appear as hyperechoic, isoechoic, or hypoechoic, depending on their stage. Acute hematomas may appear heterogenous and hyperechoic, becoming more hypoechoic or cystic over time. Subcapsular hematoma appears as a crescent-shaped fluid collection between the renal parenchyma and capsule.

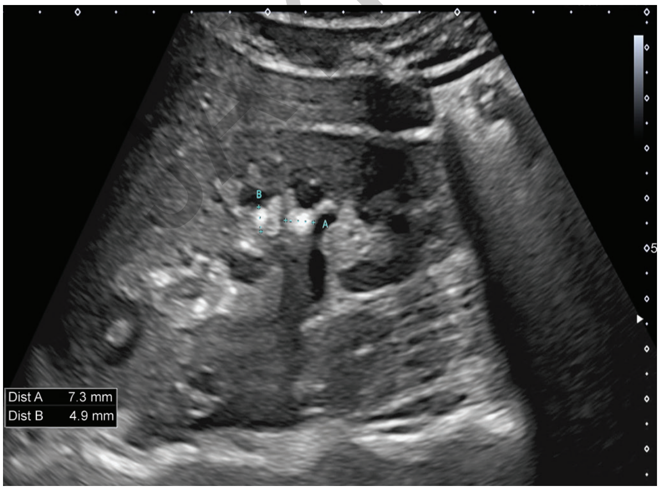


**Fig. 3:** Renal calcification/urolithiasis.

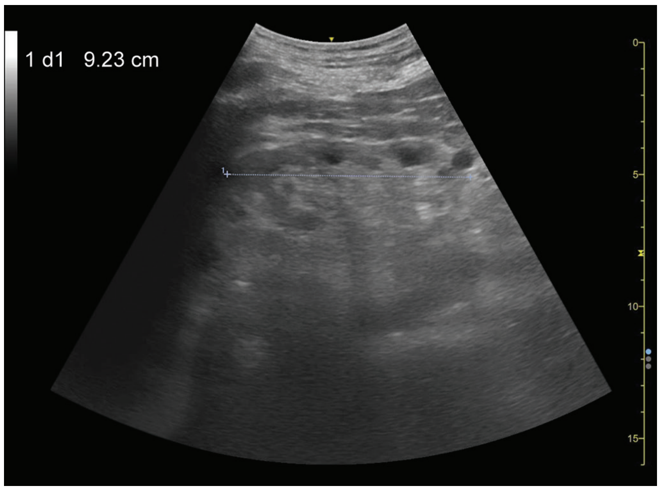


**Fig. 4:** Simple cyst at the lower pole in an atrophic kidney.

## Diffuse Changes

In health, the renal parenchyma is relatively hypoechoic and appears less echogenic than the adjacent liver or spleen.[4]

- *Cortical atrophy* **(Fig. 5)**:
  - Length usually <9 cm depending on body size
  - Length and echogenicity can be normal
  - Cortical thinning with accentuation of lobulation
  - Sign of chronic kidney disease due to the loss of functional tissue
- *Medullary disease:* Increased echogenicity leading to greater corticomedullary differentiation, which may suggest sloughing of the papillae **(Fig. 6)**

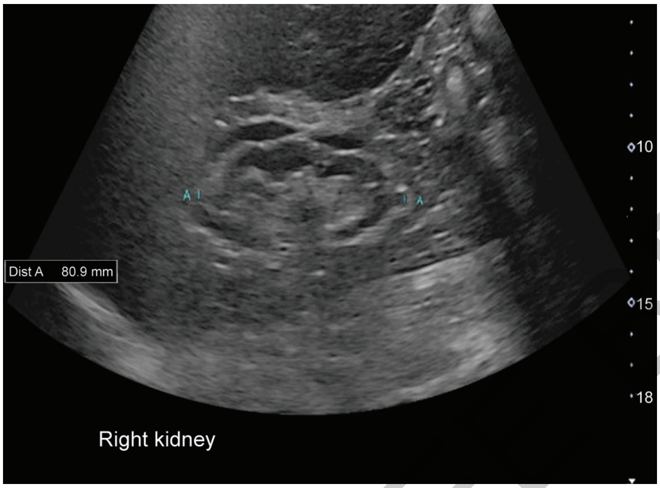


**Fig. 5:** Reduced corticomedullary differentiation demonstrating cortical atrophy in a small kidney.

- *Diffusely increased cortical echogenicity:*
  - Increased renal echogenicity is a nonspecific finding but can represent several underlying conditions.
  - Causes include various renal conditions associated with inflammation or swelling or the renal cortex or chronic kidney disease such as:
    - Acute glomerulonephritis
    - Diabetic nephropathy
    - HIV nephropathy
    - Renal amyloidosis
    - Sickle cell disease
  - Chronic glomerulonephritis leads to a decrease in renal size. The echogenicity of the parenchyma is uniformly increased. There may be loss of definition of the medullary pyramids with an indistinct corticomedullary junction.

## Hydroureteronephrosis (Figs. 7 and 8)

Ultrasound imaging of hydronephrosis will demonstrate a dilated pelvicalyceal system. The severity can be classified into mild, moderate, or severe or graded from 1 to 4 based on sonographic criteria:

- *Grade 1:* Dilated renal pelvis with no calyceal dilatation with thinning of the parenchyma
- *Grade 2:* Dilatation of the renal pelvis and calyces with thinning of the parenchyma
- *Grade 3:* Cystic dilatation of the renal pelvis with a thin rim of parenchyma
- *Grade 4:* Parenchyma no longer demonstrated

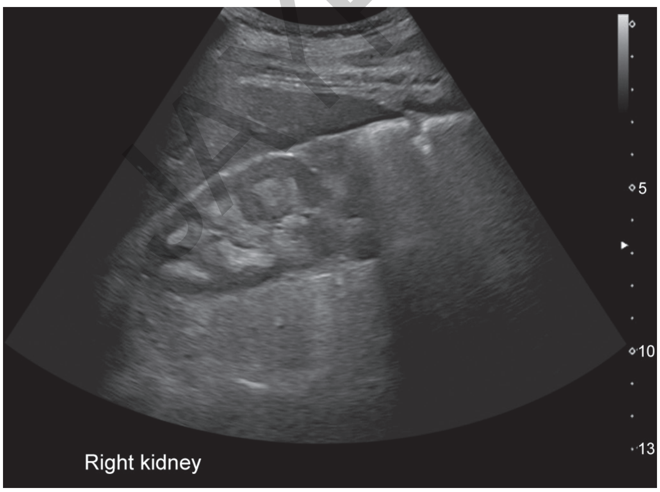


**Fig. 6:** Medullary nephrocalcinosis.

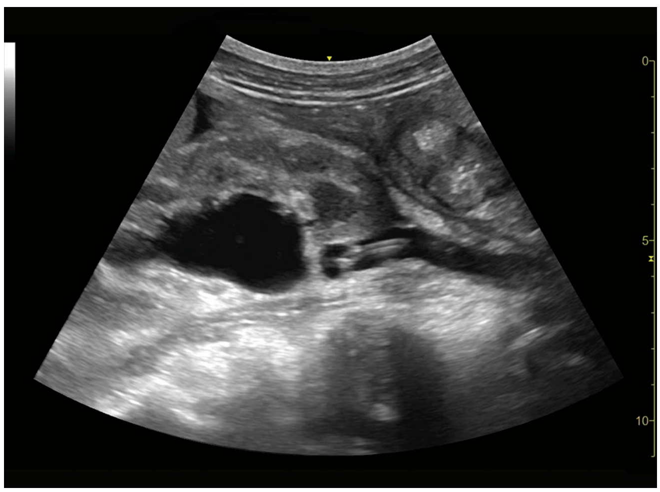


**Fig. 7:** Native left proximal ureter around blocked urinary stent and hydronephrotic kidney.

Thinning of the renal cortex in the context of hydronephrosis usually implies chronicity.

Once hydronephrosis is identified, further scanning or imaging is often required to further assess to determine the underlying cause. Always scan the lower urinary system. Dilation of the renal pelvis does not always indicate obstruction. A dilated renal pelvis can be a normal variant in some people; other causes include pregnancy, large diuresis, reflux disease, and papillary necrosis. A very full bladder may result in a bilaterally prominent pelvicalyceal system; this should be reassessed post-void for change in the degree of pelvicalyceal dilatation. Conversely, dehydration may prevent the development of hydronephrosis. Scanning may be repeated after hydration.

### Ureterolithiasis

The cause of nephrosis, including ureterolithiasis, may not always be identifiable on ultrasound, with CT imaging of the abdomen and pelvis being the gold standard for stone evaluation. Small stones can often be undetectable on ultrasound, and ureteral stones are generally difficult to visualize.

On ultrasound, calculi typically appear as bright, echogenic foci accompanied by posterior shadowing. In the renal sinus, the echo may be indistinguishable from the surrounding fat, and stones can sometimes be identified purely by the shadow. Ureteral stones are most commonly located at the UVJ. To visualize this area effectively, the ultrasound gain settings should be adjusted to make the bladder appear entirely black, while the structures behind the bladder should display varying shades of gray. Additionally, color Doppler can reveal a "twinkling artifact", characterized by alternating colors behind the stone, simulating turbulent blood flow.

Ureteric jets, which represent the normal periodic reflux of urine into the bladder, are commonly observed in well-hydrated individuals. These jets appear as brief bursts of low-level echoes from the vesicoureteral junction (VUJ) and can be seen on color Doppler as a sudden burst of color within the bladder lasting a few seconds. In cases of obstruction, no jet will be detected. With partial obstruction, the jet may show a variety of patterns, including increased or decreased flow, or even a continuous, dribbling jet.

## ULTRASONOGRAPHY OF THE BLADDER

To begin the scan, position the probe transversely above the symphysis pubis and angle it caudally. Rotate the transducer 90 to examine the bladder longitudinally along the midline, just above the symphysis pubis. Tilt the probe to visualize the entire bladder **(Figs. 9 and 10)**.

### Normal Anatomy

The bladder appears as an echogenic cavity within the pelvis. Under normal conditions, the bladder empties completely during voiding. However, in older individuals with detrusor dysfunction, there may be a residual volume ranging from 5 to 100 mL. Bladder volume can be estimated using the following formula, which includes a correction factor for the bladder's ellipsoid shape:

Bladder volume = 0.75 × width × length × height
(all in millimeters)

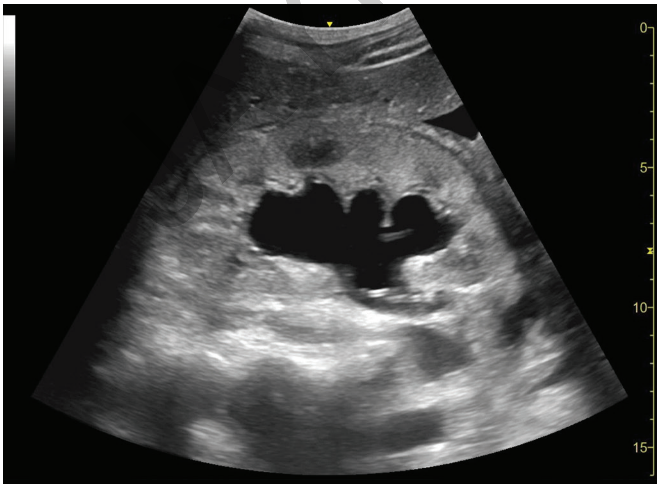


**Fig. 8:** Hydroureteronephrosis without stent.

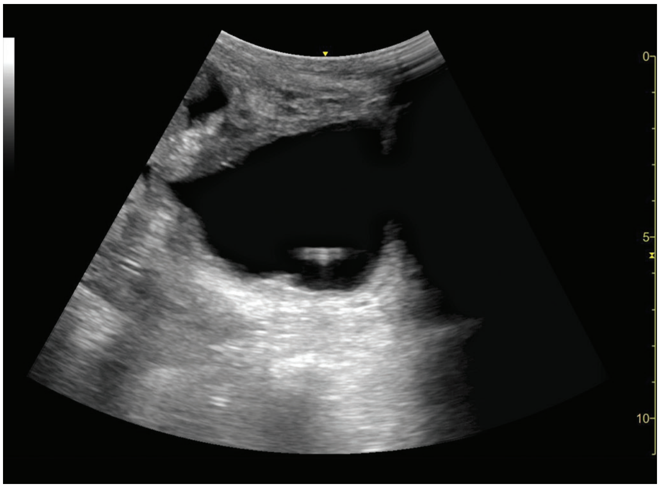


**Fig. 9:** Urinary bladder with a stent in situ.

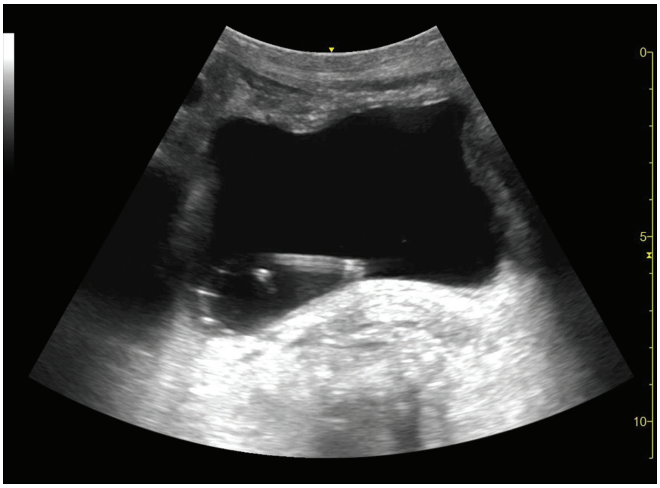


**Fig. 10:** Transverse bladder with a urinary stent.

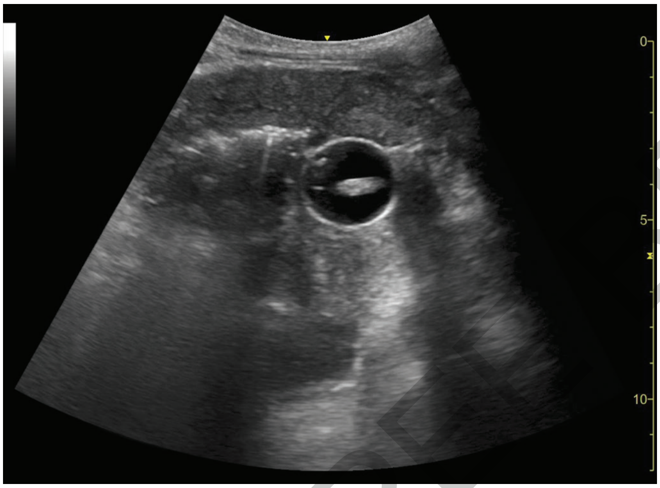


**Fig. 11:** Longitudinal bladder post-catheter insertion for macroscopic hematuria. Grossly thickened bladder wall superiorly, inflated bladder catheter balloon next to air within the remainder of bladder. Transitional cell carcinoma (TCC) confirmed on cystoscopy.

## Pathology

Bladder outlet obstruction is characterized by a bladder containing more than 100–150 mL of urine after an attempt to void. In addition to volume measurement, ultrasound can often identify conditions such as prostatic hypertrophy or neoplasm, diffuse thickening of the bladder wall from detrusor hypertrophy, and/or the presence of bladder diverticula. Additionally, bladder stones and neoplasms can be detected during the scan **(Fig. 11)**.

## CONCLUSION

The increased accessibility and widespread use of portable ultrasound has allowed it to be successfully used as an adjunct in clinical decision making. An appreciation of normal renal anatomy and ultrasound appearance is crucial in detection of variants and pathological features. There remains a significant intra and interoperator variability with subjective interpretations of imaging, highlighting the importance of formal education and additional training. Cross-sectional imaging such as CT or MRI scans may be required to assist in obtaining a definitive diagnosis.

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# Essentials of Interventional Nephrology

The future of kidney care is in intervention and more so with Interventional Nephrology: *Essentials of Interventional Nephrology*, is a comprehensive guide for clinicians, trainees, and specialists navigating the rapidly evolving field of interventional nephrology. This textbook promises to deliver cutting-edge insights into the diagnosis, management, and procedural techniques essential for optimizing patient outcomes.

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