Emergency Renal Ultrasonography

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INTRODUCTION

Acute flank pain is a common complaint in the emergency department. The presence of unilateral flank or groin pain, especially in the setting of gross or microscopic hematuria, raises clinical suspicion for renal colic secondary to an obstructing ureteral stone. Bedside renal ultrasonography is a rapid and safe imaging modality for evaluation of renal colic. The presence of unilateral hydronephrosis in the correct clinical context is often sufficient to make the diagnosis. Because pain from a rapidly expanding or leaking abdominal aortic aneurysm (AAA) can masquerade as renal colic, additional evaluation of the aorta should be considered, especially in patients with risk factors for AAA.

Acute urinary retention is a common cause of abdominal pain. Bedside ultrasound is a rapid, noninvasive diagnostic tool for the evaluation of suspected urinary retention. Sonographic estimation of urinary bladder volume provides an accurate quantitative assessment of retention in the emergency setting. Additionally, screening ultrasound for the presence of adequate urine volume has been shown to decrease the number of unsuccessful attempts at catheterization in the pediatric population.

EVIDENCE-BASED REVIEW

Computed tomography (CT) currently has the greatest sensitivity and specificity of imaging modalities used for the diagnosis of renal colic. When compared with ultrasound, non–contrast-enhanced CT is more sensitive in identifying obstructing ureteral stones1-4 and more accurate in measuring stone size.4,5 CT also more consistently locates the specific site of obstruction along the course of the ureter and can identify other causes of abdominal pain that may mimic acute renal colic.

However, routine use of CT for suspected renal colic has significant limitations. Patients are exposed to significant amounts of ionizing radiation when they undergo CT of the abdomen and pelvis,6,7 which makes CT inadvisable during pregnancy and less appealing in the pediatric population. Because renal colic is a recurrent diagnosis, patients may eventually receive multiple CT scans over time, and cumulative radiation doses may rise to concerning levels8 and place patients at risk for cancer later in life. Additionally, radiologic imaging has been shown to be the largest contributor to the cost of hospitalization in patients with renal colic, with CT being the most expensive imaging modality.9,10

Ultrasound offers a safe, noninvasive means of assessing for renal colic that does not subject the patient to any ionizing radiation. Traditionally, ultrasound has been thought to have only fair sensitivity (37% to 64%) for detecting stones and better sensitivity (74% to 85%) for the diagnosis of acute obstruction,1 whereas CT has consistently shown sensitivity greater than 90% for the diagnosis of ureteral stones.1-4 Recent studies using modern ultrasound equipment in the hands of skilled operators have demonstrated comparable sensitivity (76% to 98%) of ultrasound for the detection of ureteral stones.11-14 Although specific stone location and size cannot always be determined with ultrasound, surrogate findings may have prognostic value in guiding patient management. One study showed that normal renal ultrasound findings in the setting of suspected renal colic predicted a very low risk (0.6%) for subsequent urologic intervention.15

The goal of bedside ultrasound is to identify unilateral hydronephrosis as an indirect sign of obstructing ureteral...
stones. In the emergency department setting, Rosen et al. demonstrated a sensitivity of 72% and specificity of 73% for the detection of hydronephrosis with bedside ultrasound.16 More recently, Gaspari and Horst reported a sensitivity of 87% and specificity of 85% for the diagnosis of hydronephrosis.17 These results are comparable to a sensitivity of 81% and specificity of 92% for bedside ultrasound performed by on-call urologists; however, this study evaluated other renal findings in addition to hydronephrosis.18 Although the specific size of the obstructing stone is not typically demonstrated on bedside ultrasound, the degree of hydronephrosis may correlate with the size of the obstructing stone. A 2010 study showed that no or mild hydronephrosis predicted smaller stone size (<5 mm) as opposed to moderate or severe hydronephrosis.19

Bedside ultrasound for the measurement of urinary bladder volume has been well described in the literature. Bedside ultrasound provides a quantitative assessment of bladder volume when evaluating for urinary retention in the emergency department setting and can guide the need for emergency catheterization.20,21 Many studies have shown good correlation between sonographic bladder volume calculations and urine volumes obtained via catheterization.22-24 In the pediatric population, ultrasound has been shown to predict patients with volumes sufficient for successful catheterization of urine samples (>3 mL).25-28 This may help avoid multiple attempts at urinary catheterization, which can result in unnecessary patient discomfort and the potential for iatrogenic infection. Additionally, bedside ultrasound has demonstrated increased success rates during attempts at suprapubic aspiration when compared with traditional, landmark-based techniques.29-31

**HOW TO SCAN**

Emergency renal ultrasonography is performed with a 2- to 5-MHz curvilinear transducer. When rib shadows limit adequate sonographic windows for the kidneys, switching to a phased-array probe may be helpful. In general, patients can be positioned supine for renal ultrasound. The right lateral recumbent position may be necessary when imaging the left kidney because this kidney tends to be located more posteriorly and the spleen is not as large an acoustic window as the liver.

For the right kidney, the probe is initially placed along the lower portion of the rib cage in the midaxillary line with the probe marker directed toward the patient’s head. The resulting coronal view is the traditional right upper quadrant view of the focused assessment with sonography for trauma (FAST) examination. The kidney lies in a plane oblique to the long axis of the body, and the probe usually needs to be rotated slightly counterclockwise to obtain a maximally longitudinal view of the kidney (Fig. 115.1, A). This orientation also helps the ultrasound transducer align the image in between the ribs, thus minimizing rib shadows. The transducer should then be angled anterior to posterior so that it fans through the entire kidney. To obtain a transverse view of the kidney, the probe is rotated 90 degrees in a counterclockwise direction (Fig. 115.1, B). The transducer should then be fanned superior to inferior to image the entire kidney in the transverse plane.

For the left kidney, the probe is initially placed along the lower part of the rib cage in the posterior axillary line with the probe marker directed toward the patient’s head. The resulting coronal view is the traditional left upper quadrant view of the FAST examination. The transducer often needs to be moved relatively posterior and superior with respect to the right side to obtain adequate views of the left kidney. The spleen is not as large an acoustic window as the liver, and bowel gas from the stomach and colon may interfere with images of the left kidney. When a satisfactory sonographic window is located, the probe should be rotated slightly clockwise to maximize the longitudinal view of the kidney and align the transducer in between the ribs. The transducer should then be angled anterior to posterior to fan through the entire kidney. To obtain a transverse view of the kidney, the probe is rotated 90 degrees in a counterclockwise direction. The transducer should then be fanned superior to inferior to image the entire kidney in the transverse plane.

To image the urinary bladder, the transducer is placed in the midline above the symphysis pubis with the probe marker directed toward the patient’s head. The resulting sagittal view is the traditional pelvic view of the FAST examination. The transducer should then be moved or angled to the right and left to image the entire bladder. To obtain a transverse view
of the bladder, the probe is rotated 90 degrees counterclockwise so that the probe points toward the patient’s right. The transducer should then be moved or angled superior and inferior to image the entire bladder.

When measuring urinary bladder volume, the bladder should first be imaged in the transverse plane at the level where the largest view of the bladder is obtained. The image is frozen, and bladder depth and width are measured (Fig. 115.2, A). The bladder is then imaged in the sagittal plane, again at the level where the largest view of the bladder is obtained. The image is frozen, and bladder height is measured (Fig. 115.2, B). Bladder volume can be estimated with the simplified formula $0.75 \times \text{depth} \times \text{width} \times \text{height}$. On many ultrasound machines, software will automatically calculate bladder volume by using measurements obtained by the sonographer.

**IMAGES—NORMAL AND ABNORMAL**

The kidneys are paired, bean-shaped retroperitoneal structures that lie slightly oblique to the long axis of the body. A normal kidney measures 9 to 12 cm in length and is between 4 and 5 cm in width. A difference of up to 2 cm in measurements between the right and left kidney is considered within the normal range. On longitudinal images, the kidney will appear oval in shape (see Fig. 115.1, A); on transverse images, the kidney will appear circular (see Fig. 115.1, B).

The kidneys consist of a renal cortex, medullary pyramids, and renal sinus (see Fig. 115.1). The renal cortex has a homogeneous sonographic appearance and is slightly less echogenic than normal liver and spleen. The medullary pyramids may or may not be well visualized on bedside sonography. They appear as multiple hypoechoic cone-shaped structures between the renal sinus and cortex, with their apices directed toward the renal sinus. The renal sinus appears hyperechoic because of its fibrous and fatty tissue content. The renal collecting system, which consists of the renal pelvis and multiple calices, resides within the renal sinus. The kidney is surrounded by a hyperechoic fibrous capsule (Gerota fascia), as well as perinephric fat.

Hydronephrosis is manifested as varying degrees of dilation of the collecting system as a result of distal obstruction. It is best visualized on longitudinal images of the kidney. Hydronephrosis may be graded as mild, moderate, or severe. Mild hydronephrosis is defined as dilation of the renal pelvis and blunting of the normally concave renal calices. Anechoic areas will appear in the normally hyperechoic renal sinus as fluid fills and distends the renal pelvis (Fig. 115.3, A). Mild hydronephrosis may be difficult to appreciate on bedside ultrasound. Careful comparison with the contralateral kidney can help reveal more subtle cases of unilateral hydronephrosis. Prominent renal vessels within the renal sinus may be mistaken for mild hydronephrosis. Application of color flow or power Doppler can help differentiate whether an anechoic space within the renal sinus is due to blood vessels or actual dilation of the renal pelvis. Moderate hydronephrosis is defined as more prominent dilation of the renal pelvis and rounding of the renal calices (Fig. 115.3, B). Severe hydronephrosis is defined as extreme calyceal distention causing thinning of the renal cortex (Fig. 115.3, C). When chronic, hydronephrosis can result in a marked degree of cortical atrophy. In the setting of acute obstruction, calyceal rupture may occur and result in a urinoma. A urinoma appears as a stripe of anechoic free fluid surrounding a portion of the kidney.

Kidney stones appear as brightly echogenic structures and will exhibit posterior acoustic shadowing when sufficient size has been attained. Obstructing ureteral stones are not typically visualized directly during bedside ultrasonography. Non-obstructing stones within the renal pelvis are more frequently visualized, although they may be hard to distinguish from adjacent hyperechoic fibrofatty tissue within the renal sinus. Obstructing stones may occasionally be visualized at the ureteropelvic or ureterovesical junction. Obstructing stones within the remainder of the ureter are more challenging to identify because of overlying bowel gas. The ureters themselves are not discernible during bedside ultrasonography unless significantly dilated.

Renal cysts appear as rounded anechoic structures with thin, smooth walls and exhibit posterior acoustic enhancement (Fig. 115.4). Though not a primary indication for performing emergency renal ultrasonography, renal cysts are not an uncommon finding and occur in roughly 50% of patients 50 years or older. When internal echoes, septations, or thick walls are visualized, other diagnoses, such as a hemorrhagic cyst, renal
HOW TO INCORPORATE INTO PRACTICE

Ultrasound serves as a valuable initial screening examination in patients suspected of having renal colic. It can be performed directly at the bedside by the emergency physician to rapidly categorize the likelihood of an obstructing ureteral stone. Though not specifically studied in the setting of renal colic, bedside ultrasound has been shown to expedite patient care and decrease length of stay in the emergency department when performing other focused studies.\textsuperscript{34,35} Bedside ultrasound may also speed the identification of life-threatening conditions such as a leaking AAA when being considered in the differential diagnosis.\textsuperscript{36}

In patients with clinical findings suggestive of renal colic, especially in those with microscopic or gross hematuria, the presence of unilateral hydronephrosis may be adequate evidence of a ureteral stone. If findings on the initial bedside ultrasound are normal, it may be repeated after a period of hydration, which can subsequently reveal hydronephrosis. When mild to moderate hydronephrosis is identified as a surrogate for an obstructing ureteral stone, the patient may undergo standard treatment of renal colic. When severe hydronephrosis is seen as a new finding, comprehensive imaging by radiology and urgent urologic consultation are advised.\textsuperscript{36,37}

Ultrasound may be especially helpful in patients with known renal colic who have recurrent or worsening pain. In these patients, in whom the diagnosis of renal colic has already been established, ultrasound is an excellent tool to screen for significant obstruction and assess for complications of obstructing stones, such as calyceal rupture and resultant abscess, or carcinoma, are more likely. Making these diagnoses is outside the scope of bedside ultrasonography, and such findings should prompt comprehensive radiologic imaging. Additionally, any structure that distorts the normal renal architecture is concerning for malignancy. Renal cancers and pseudoaneurysms may have an appearance similar to simple renal cysts,\textsuperscript{35} and it is recommended that color flow or power Doppler be applied to evaluate for internal blood flow within any cystic structure seen in the kidneys.
important to remember that urinary retention, especially when prolonged, may lead to bilateral hydronephrosis, and ultrasound evaluation of the kidneys should reflexively follow identification of a distended bladder.

In the pediatric population, bedside ultrasound may guide the timing of urinary catheterization. Attempts at catheterization are unsuccessful in obtaining urine from pediatric patients approximately 25% of the time. In cases in which suprapubic bladder aspiration is indicated to obtain a urine sample, ultrasound provides procedural guidance and increases the rate of successful bladder taps.

In summary, bedside ultrasound is a rapid, noninvasive imaging modality useful for the evaluation of flank pain. It may identify hydronephrosis as a surrogate finding in patients with renal colic and can be used to exclude AAA from the differential diagnosis. Ultrasound can also assist in the diagnosis of urinary obstruction and provide guidance for the timing of urinary catheterization in children. Emergency renal sonography is a focused application that must be interpreted within the clinical context of the patient’s signs and symptoms. Patients with findings outside the scope of the bedside ultrasound examination should be referred for consultative radiologic imaging.

**REFERENCES**

References can be found on Expert Consult @ www.expertconsult.com.
REFERENCES