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Renal ultrasound

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There are a number of diagnostic imaging modalities available to assist in the evaluation of patients who present to the emergency department (ED) with acute urologic disease. Traditionally, intravenous pyelography (IVP) was the test of choice but, in recent years, it has been supplanted by helical CT. Ultrasound (US), angiography, and MRI are the other available diagnostic imaging modalities. US is a particularly attractive option for many emergency physicians (EPs) because it is noninvasive, can be performed at the bedside, and does not require exposure to contrast material or radiation. Moreover, many EPs have acquired the skills to perform limited, focused examinations themselves. This article reviews the role of formal renal US in the evaluation of acute urologic emergencies, focusing on clinical indications, radiologic findings, and relative merits compared with other diagnostic modalities. This article also reviews the indications for bedside renal US performed and interpreted by EPs and summarizes the growing body of evidence in support of this practice. In addition, the technique of performing the US examination is reviewed.

Formal renal ultrasonography

Formal renal US is a detailed examination of the renal and urologic systems performed by a radiologist or radiology technician. US has several advantages over other diagnostic imaging modalities: it provides excellent detailed renal anatomic information (Fig. 1), it can be performed at the bedside without moving the patient to an unmonitored setting, it can provide information about other organ systems when the EP suspects alternative diagnoses, and it is noninvasive. In addition, it does not expose the patient to radiation or require the administration of iodinated intravenous (IV) contrast, which is

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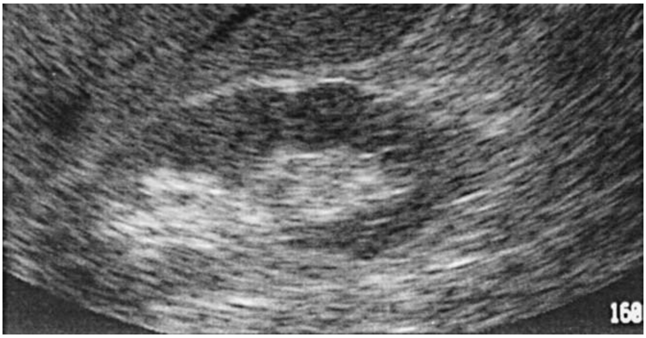

Fig. 1. Normal right kidney on longitudinal view. Note the echogenic white Gerota's fascia, the grainy gray renal cortex, and the central echogenic pelvicalyceal structures. (*From* Brown DFM, Rosen CL, Wolfe RE. Renal ultrasonography. Emerg Med Clin N Am 1997;15:878; with permission.)

important because IV contrast administration has two major drawbacks: it is nephrotoxic [1] and may be contraindicated in patients with renal insufficiency [2]. IV contrast also can cause allergic reactions—most significantly, anaphylaxis, which can be life threatening.

US has several limitations: it is more operator dependent than other modalities and, despite its anatomic detail, can provide only limited assessment of renal function, unlike CT or IVP. If the US machine is capable of Doppler technology and both ureter jets are observed, however, global renal function can be assumed [3]. The ED indications for formal renal ultrasonography are listed in Box 1 and are discussed in detail in the following sections.

Renal colic

Renal colic is one of the most common diseases of the urinary tract. It is estimated that 2% to 5% of the population will form a urinary stone at some point in their lives [4]. Renal colic is the term used to describe the

Box 1. Emergency department indications for formal renal ultrasound

Renal colic
Acute renal vein thrombosis
Renal failure
Renal mass
Acute renal infection
Renal trauma
Urinary retention

abrupt, severe, sharp flank and low back pain caused by the acute obstruction and distention of the ureter and renal pelvis. Associated symptoms include nausea, vomiting, diaphoresis, and radiation of pain to the groin. The most common cause of renal colic is ureterolithiasis, although obstruction of the ureter also may be due to ureteral spasm, thrombus formation within the ureter, or the presence of sloughed papillae within the ureter in the setting of acute papillary necrosis. The diagnosis of nephrolithiasis frequently is made on clinical grounds in patients with microscopic hematuria and the appropriate history. In many patients, however, a confirmatory imaging study is needed.

IVP, long the radiologic mainstay in the diagnosis of renal colic, largely has been supplanted by helical CT in the last several years [5–14]. CT has a shorter examination time, provides better visualization of the calculus, and allows its measurement anywhere along the urinary tract, including the bladder. In addition, CT gives detailed information about other abdominal structures, which can be useful if the cause of the symptoms is not within the urinary tract. Generally, CT is performed without the administration of IV iodinated contrast. If the stone is not visualized, then IV contrast may be used to look for other causes of pain and hematuria. When contrast is added, CT also can provide an accurate assessment of renal function and renal vasculature. CT, however, carries the same risk of radiation exposure as IVP and, when contrast is used, carries the same allergic and nephrotoxic risks outlined in the previous section [49].

The overall advantages of CT usually make formal renal US the second choice in diagnostic imaging of suspected renal colic. Renal US may identify the actual calculi, which are seen as small echogenic structures with posterior shadowing (Fig. 2), particularly when the calculi are intrarenal. Intraureteral stones are very difficult to demonstrate, especially when they are small or in obese patients [15,48]. More commonly, US will reveal some degree of unilateral hydronephrosis, a sign of ureteral obstruction. Hydronephrosis occurs when the central calyceal system is dilated with urine, and appears sonographically as dark black and homogeneously anechoic (Fig. 3) [16]. It can be characterized as mild, moderate, or severe (Table 1), but these characterizations have poor correlation with the degree and acuity of obstruction [17]. The test characteristics for ultrasonographic detection of urinary tract calculi depend on which diagnostic criteria are used (direct visualization of the stone, unilateral hydronephrosis, or both). Using both criteria, Sinclair and associates [18] demonstrated a sensitivity of 85% and a specificity of 100% for US (compared with 90% and 94%, respectively for IVP). The presence of an identifiable calculus alone as the diagnostic criterion yielded a sensitivity of 64% and a specificity of 100%; the presence of obstructive hydronephrosis alone had a sensitivity of 85% and a specificity of 100% [18]. Svedstrom and colleagues [19] demonstrated that plain radiographs and US each had a sensitivity of 60%, but when used together, the sensitivity rose to 80% for the diagnosis of nephrolithiasis. Other

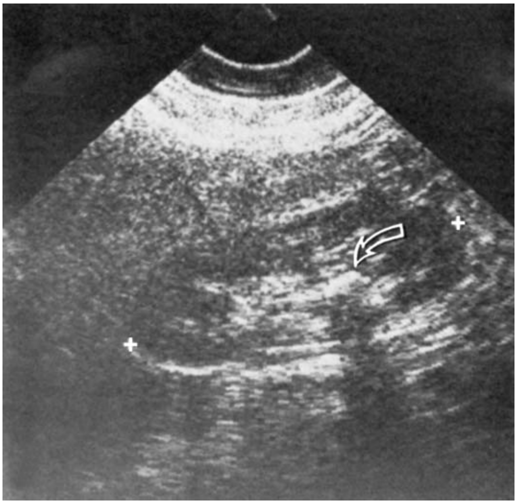

Fig. 2. Renal stone. Longitudinal view of kidney containing a hyperechoic calculus (*open arrow*) with posterior acoustic shadowing. (*From* Van Arsdalen KN, Banner MP, Pollack HM. Radiographic imaging and urologic decision making in the management of renal and ureteral calculi. Urol Clin N Am 1990;17:186; with permission.)

investigators have described similar results when combining results of US and plain radiographs, thus approaching the diagnostic accuracy of IVP [20,21]. More applicable to current clinical practice, however, are the studies that compare US with noncontrast helical CT. Fowler [8] showed that US depicted 24 of 101 calculi identified on CT, for a sensitivity of 24% and

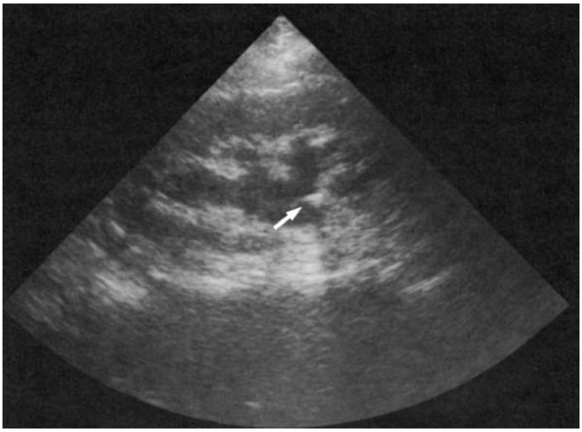

Fig. 3. Hydronephrosis. Longitudinal view of the kidney reveals dilated renal collecting system and pelvis. Note the calculus in the renal pelvis (*arrow*). (*From* Chang TS, Lepanto L. Ultrasonography in the emergency setting. Emerg Med Clin N Am 1992;10:8; with permission.)

Table 1
Grades of hydronephrosis

Grade I	Grade II (mild)	Grade III (moderate)	Grade IV (severe)
Slight blunting of calyceal fornices	Obvious blunting of calyceal fornices and enlargement of calices, but intruding shadows of papillae easily are seen	Rounding of calices with obliteration of papillae	Extreme calyceal ballooning

Adapted from Grainger RG, Allison DJ, editors. Diagnostic radiology: a textbook of medical imaging. 4th edition. London: Churchill Livingstone; 2001; p. 1594.

a specificity of 90%. No difference in stone detection of the left versus the right kidney was found for US. Smith and colleagues [12] showed that CT was more sensitive and specific than KUB, US, IVP, or any combination of the these diagnostic modalities. The value of nonenhanced helical CT was demonstrated by its sensitivity of 97%, specificity of 96%, and overall accuracy of 97%. Finally, in a prospective comparison of US and non-enhanced helical CT, Sheafor and colleagues [10] showed that CT identified 22 of 23 known stones, for a sensitivity of 96%, whereas US identified 14 of 23 calculi, for a sensitivity of 61%. Both tests had a specificity of 100%. When the tests were compared for any clinically relevant abnormality (unilateral hydronephrosis or urolithiasis with obstructing calculus), the sensitivities of US and CT increased to 92% and 100%, respectively. US missed one case of appendicitis as an alternative diagnosis and CT missed one case of medullary calcinosis [10]. Despite this evidence for CT superiority, US remains the test of choice for pregnant women; when helical CT is not available; and for those patients with relative contraindications to IV contrast such as allergy, renal insufficiency, and diabetes mellitus when dye must be used.

Renal failure

For ED patients with newly diagnosed or worsening renal failure, US remains the imaging modality of choice because contrast material is not required. The causes of renal failure classically are categorized as prerenal, postrenal, or intrinsic to the kidney. US immediately is helpful in immediately identifying postrenal causes of failure because obstruction (ureteral or urethral) can be ruled out by the absence of hydronephrosis and a quick estimation of bladder size [17,22,23]. Moreover, prostatic enlargement, a common cause of lower tract obstruction, also can be identified on US [16]. Prerenal causes of renal failure generally will not be associated with sonographic abnormalities, but intrinsic causes often will have notable findings. The first issue to address using US is that of renal size, which gives a rough indication of the chronicity of the renal failure. Enlarged kidneys suggest an acute case of renal failure, such as infection, renal vein thrombosis, or transplant rejection. Small kidneys imply chronic disease. In addition, an assessment of the echogenicity of the renal parenchyma can be made. An increase in echogenicity suggests chronic renal failure (Fig. 4) [15]. Finally, identification of a solitary kidney is important in any evaluation of new renal failure and readily is readily accomplished by US.

Acute renal infection

Pyelonephritis, an infection of the upper urinary tract, is a very common ED diagnosis and usually does not require imaging studies for diagnosis or management. Patients present with flank pain, fever, nausea and vomiting, pyuria, and bacteriuria. A small subset of these patients will progress to focal abscess formation that is resistant to standard antibiotic therapy and requires diagnostic imaging. Renal US in uncomplicated pyelonephritis generally reveals a normal-appearing kidney, although in some patients, the involved kidney may become enlarged with hypoechoic foci at the corticomedullary junction [15,16,24]. As the disease process becomes more advanced, these foci become larger, representing areas of bacterial nephritis. Renal abscesses are identified as larger, well-defined hypoechoic masses that occasionally may appear cystic. Emphysematous pyelonephritis is a rare bacterial infection generally limited to people who have diabetes. It can be diagnosed by renal US when high-amplitude echoes are seen within the renal parenchyma or sinus, with shadowing that contains low-level echoes and reverberations [25,26]. Plain abdominal radiographs or CT scans can confirm the presence of gas within the renal parenchyma. Distention of the pelvis and calyces of the kidney with pus can occur when infection develops in an obstructed kidney and is suggested on US by the presence of echoes in a dilated collecting system.

Fig. 4. Renal failure. Longitudinal scan of right kidney demonstrates an increase in the echogenicity of the renal parenchyma suggesting acute renal failure. (Courtesy of D. Riley, MD, St. Luke's/Roosevelt Hospital, New York).

Finally, perinephric abscess can be detected by US, appearing as circumscribed fluid collections around the involved kidney. These collections often have internal septations or mobile debris, appear hypoechoic, and have a degree of posterior acoustic enhancement [27,28]. Usually when these findings are seen, further evaluation with CT scanning is indicated.

Urinary retention

As mentioned previously, postrenal causes of renal failure are assessed rapidly with US by looking for obstruction and bladder distention. In addition, US is useful for patients presenting with complaints of urinary retention, urgency, or incontinence. In these clinical situations, bladder volume can be estimated by measuring the bladder at its maximal width, depth, and length and applying the following formula: width $\times$ depth $\times$ length $\times$ 0.75 [29]. Any patient with a postvoid residual volume greater than 100 mL has urinary retention. The prostate can be assessed while looking at the bladder and is best seen on transverse views at the bladder neck. A normal prostate should be 5 cm in width. In addition, the bladder wall can be assessed and should be smooth and of uniform thickness. The wall thickness depends on the degree of bladder distention, but as a rule of thumb, a thickness greater than 5 mm is abnormal [30]. The technique for scanning the bladder is simple. The probe should be placed just superior to the patient's symphysis pubis and angled toward the patient's feet. The bladder should be scanned in the sagittal and transverse planes.

Acute renal vein thrombosis

Patients with acute renal vein thrombosis present with flank pain and tenderness, hypertension, and proteinuria. It particularly is prevalent in patients with renal transplants but also should be suspected in patients with nephrotic syndrome, malignancy, infections, and trauma. Significant improvements in MRI and MRV technology have greatly expanded their role in the evaluation of acute renal vein thrombosis [31]. Contrast enhanced CT scanning or angiography, however, remain the mainstay for diagnosis, except in certain clinical conditions or populations (pregnancy, pediatrics, transplant recipients) where renal US is preferred [31]. US is diagnostic when it includes Doppler studies that show the absence of blood flow in the renal vein [28,50].

Renal masses

Renal masses are being identified with increasing frequency in the ED because of increased use of emergency sonography and other imaging modalities [32–35]. Although rarely of emergent clinical significance, these masses, after being identified, always deserve referral and further diagnostic imaging (often a CT scan). There is no question that the morbidity and mortality of patients are improved by detection of malignancies before they are symptomatic [33]. In addition, polycystic kidney disease may be identified in the ED because it can present with hematuria, flank pain, hypertension, and renal failure. The multiple cysts of varying sizes in both kidneys that enlarge and distort regular renal architecture are best identified by US [27,28]. If these findings are observed, referral for further workup is mandatory.

Renal trauma

The kidney frequently is injured in victims of trauma. Although increasingly, these injuries are being managed nonoperatively, many still require surgery to control hemorrhage and to prevent delayed abscess formation and hypertension. Concern for missing a surgical lesion results in the high use of radiologic studies. Contrast enhanced CT scanning is the diagnostic imaging test of choice because it provides information about renal function and vascular status in addition to detailed anatomic data [36]; however, US plays a role in the evaluation of renal injuries in trauma.

The traditional role for renal US in trauma is as part of the Focused Assessment with Sonography for Trauma (FAST) examination, whereby it is used as a screening tool to look for intraperitoneal fluid. The specifics of the FAST examination are discussed in other articles within this issue, but it should be noted that it is not designed to pick up renal injuries but only identifies intraperitoneal fluid, suggesting ongoing hemorrhage or other abdominal catastrophes necessitating laparotomy. For specific renal injuries, US has been found to be highly reliable in distinguishing renal contusion from more serious injuries in Austria, although these results have not been reproduced in trauma centers in the United States [37,38]. In addition, renal US can show bleeding into the retroperitoneal space as a hypoechoic area around the kidney, although the sensitivity for US in diagnosing retroperitoneal hemorrhage is low. Focal areas of parenchymal hemorrhage and edema may be seen as hypoechoic areas within the kidney. A linear, reproducible absence of echoes suggests renal fractures. If the collecting system is injured, then urine may leak out of the kidney yet be contained between the renal capsule and Gerota's fascia, creating a urinoma (Fig. 5). A urinoma should be considered when an anechoic ring is seen around a portion of the kidney. Although US is a sensitive method for demonstrating a urinoma, the differential diagnosis includes lymphocele, hematoma, abscess, cyst, and ascites. Patients with this finding require further testing [27,28]. New technologic advances such as power color Doppler may provide an alternative diagnostic strategy to CT for the diagnosis of renal perfusion injuries. This technique deserves further study because it has not been thoroughly evaluated in the trauma setting [16]. One

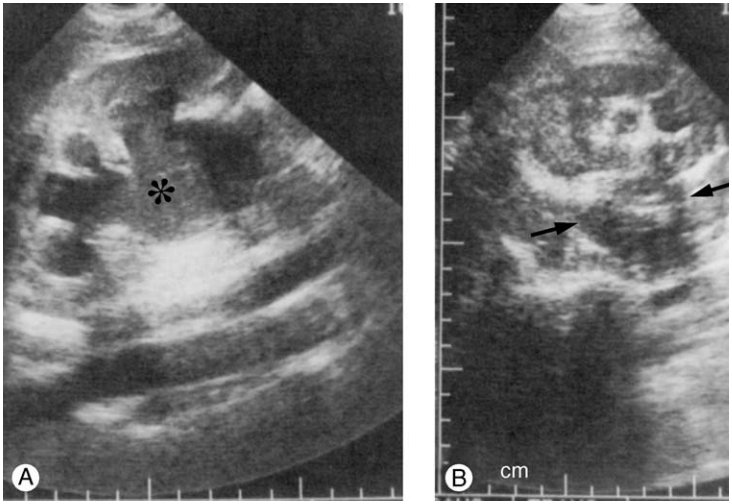

Fig. 5. Blunt renal trauma. (*A*) Longitudinal section of right kidney shows hydronephrosis with echogenic material in the collecting system (*asterisk*). Note the clubbed calyxes. (*B*) Transverse view demonstrates a mixed-density fluid collection medial to the kidney (*arrows*). Diagnosis was ureteropelvic junction obstruction with blood in the dilated collecting system and perinephric urinoma/hematoma. (*From* Loberant N. Emergency imaging of the urinary tract. Emerg Med Clin N Am 1992;10:75; with permission.)

final important role for US in renal trauma is in the management of patients with identified parenchymal injuries such as hematomas and lacerations. These lesions often are well visualized and can be evaluated periodically to monitor their resolution so that patients do not need to undergo further testing with radiation exposure risks [16,38].

Renal ultrasound performed by emergency physicians

The use and acceptance of limited emergency abdominal US performed and interpreted by EPs has increased during the past decade. US training now is part of the core content for residency training in emergency medicine. In addition, standards for performing US and requirements for training have been published by the American College of Emergency Physicians and are the current standard for emergency medicine [39]. Emergency US generally is performed at the bedside in the ED using a portable machine and is designed to answer simple clinical questions. It is not intended to be a comprehensive formal US. Emergency renal US performed by EPs has the same previously described advantages and limitations as formal US compared with other diagnostic imaging modalities. In addition, emergency renal US offers several advantages over conventional formal renal US: it is immediately available regardless of the time of day and patients do not have to leave the ED to go to the radiology suite or other minimally monitored settings. The examining physician performs the US and so the evaluation can be focused on the patient's signs and symptoms. It is repeated easily one or more times as clinical parameters change or to monitor response to therapy [47]. For example, it is well known that dehydrated patients will have false-negative US findings when looking for hydronephrosis. After IV hydration, these same patients often develop significant findings on repeat examinations [16]. Finally, the physician performing the examination can look at other abdominal structures, especially the abdominal aorta, to help in the consideration of alternative diagnoses.

The literature that supports ED ultrasonography by EPs continues to grow. Mandavia [40] provided a prospective analysis of the impact of a US training program on a residency training program. After an introductory course (16 hours) and minimal hands-on training, it was reported that emergency medicine residents had a sensitivity of 92% and a specificity of 96% on 1138 focused US examinations. These focused US examinations were a combined group of all six ACEP-indicated US categories (renal, pelvic, trauma, right upper quadrant, aortic, and cardiac). Lanoix [36], in describing the introduction of a US curriculum into a training program, concluded that "with a minimal amount of training [residents] display acceptable US technical skill and interpretive acumen." Specifically, renal US as performed by residents was reported to be 94% sensitive and 96% specific for ruling out hydronephrosis. The resident-performed US examinations were over-read by radiologists or certified ultrasonographers to determine their accuracy. Among earlier studies, Rosen and colleagues [41] described their experience with EP-performed renal US. Renal US examinations were performed by EP operators with limited training (5-hour introductory course) and were found to have a sensitivity of 71%, a specificity of 75%, a positive predictive value of 83%, and a negative predictive value of 60% for detecting hydronephrosis compared with IVP. Henderson and colleagues [42] also compared EP-performed renal US with a plain radiograph of the abdomen (KUB) and IVP. They found that minimally trained EPs had a sensitivity of 97% but a specificity of 59% in detecting hydronephrosis. Their positive predictive value was 80.7% and their negative predictive value was 92%. One of the reasons for the higher sensitivity in this study was that all patients received a 500-mL bolus of normal saline before US. All of these studies lend support to the idea that minimally trained EPs can use renal US to diagnose hydronephrosis accurately.

Technique

The technique of emergency renal US performed by EPs is simple. It can and should be performed at the bedside, obviating the need to move the patient. The study begins with the patient supine. Generally a 3.5-MHz transducer is used, although a 5-MHz probe can provide high-quality images in thin patients and in children. The right kidney is more easily accessible to US because it is located adjacent to the liver, which serves as an excellent acoustic window. The probe should be placed (with the marker toward the patient's head) along the right lateral subcostal margin in one of the lower right intercostals spaces in the anterior axillary line, scanning through the liver to locate the right kidney. When bowel gas is present, it will reflect the US waves and obscure the right kidney in this position. The probe then should be moved laterally to the mid or posterior axillary line. After the kidney has been visualized, the position of the probe should be adjusted slowly to obtain the optimum longitudinal view. Thereafter, the probe should not be moved along the skin but rather rocked slowly back and forth to sweep medially and laterally through the kidney in the longitudinal plane (long-axis view). The probe then should be rotated 90° to visualize the kidney in the transverse plane (short-axis view).

The left kidney is more difficult to visualize because of overlying bowel gas or air in the stomach, its more superior location, and the absence of the liver to provide an acoustic window. US of the left kidney is performed with the probe placed in the posterior axillary line or in the left costovertebral angle with the patient in the right lateral decubitus position. After the left kidney is located, the scanning technique is the same as for the right. Views should be obtained in the longitudinal and transverse planes.

For both right and left kidneys, it is important to visualize the kidney longitudinally and include the tip of the inferior pole because fluid often collects there first as it is the most dependent position. An important US technique is to have the cooperative patient inspire and hold his or her breath. This action will displace both kidneys inferiorly as much as 2.5 cm and may provide a more optimal view [43].

Normal kidneys measure 4 to 5 cm in width, 9 to 12 cm in length, and generally are within 2 cm of each other in length [44]. Each kidney has an echogenic capsule that represents Gerota's fascia and surrounding perinephric fat [15,43]. The kidney has a long-axis appearance that is football shaped (Fig. 6), and is round or C shaped when viewed along its short axis (Fig. 7). The renal sinus is composed of renal vessels, the pelvicalyceal system, and surrounding fibrous and adipose tissue. It appears on the long-axis as a bright, echodense central complex surrounded by less echodense parenchyma. On transverse view, the central collecting system structure is echodense, round in shape, and more medially located.

Focused emergency department ultrasound objectives

The focus of the bedside renal US examination in ED patients is to determine the presence or absence of hydronephrosis as an indicator of urolithiasis (Fig. 8). The bright echodense central collecting system will be

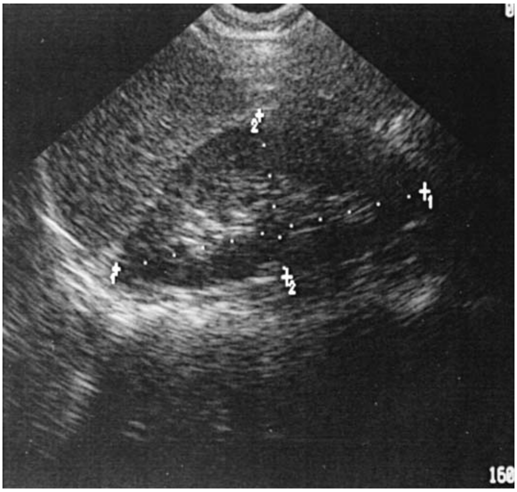

Fig. 6. Longitudinal view of normal kidney with length and width measurements. (*From* Brown DFM, et al. Renal ultrasonography. Emerg Med Clin N Am 1997;15:887; with permission.)

distended by homogeneous black anechoic branching areas that represent fluid in the renal pelvicalyceal space [15]. Hydronephrosis must be distinguished from renal cysts that also appear as anechoic collections of fluid within the kidney (Fig. 9). Scanning through the kidney in real time can make this distinction. Hydronephrosis is distributed within the collecting

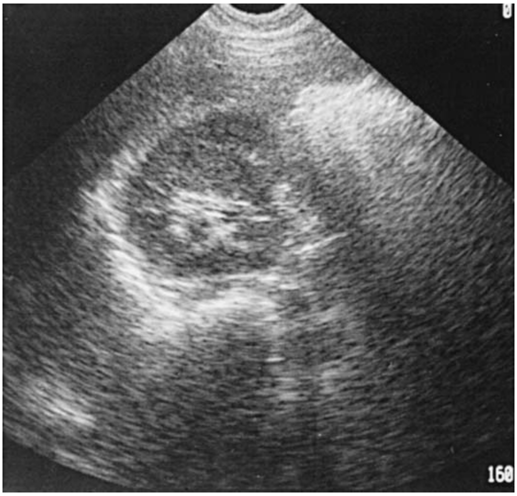

Fig. 7. Transverse (short-axis) view of normal kidney. Note the echogenic white Gerota's fascia, the grainy gray renal cortex, and the central echogenic pelvicalyceal structures. (*From* Brown DFM, et al. Renal ultrasonography. Emerg Med Clin N Am 1997;15:887; with permission.)

Fig. 8. Hydronephrosis. Longitudinal view of right kidney with dilated collecting system.

system, whereas cysts will be located focally within the renal cortex, with a normal-appearing collecting system. It also is important to distinguish hydronephrosis from an extrarenal pelvis, a commonly seen normal variant. In these patients, the collecting system generally is outside the kidney, appearing as a medial anechoic fluid collection that can be mistaken for a sign of obstruction. The EP also should look for a perinephric fluid collection, which may represent calyceal rupture and extravasation of urine

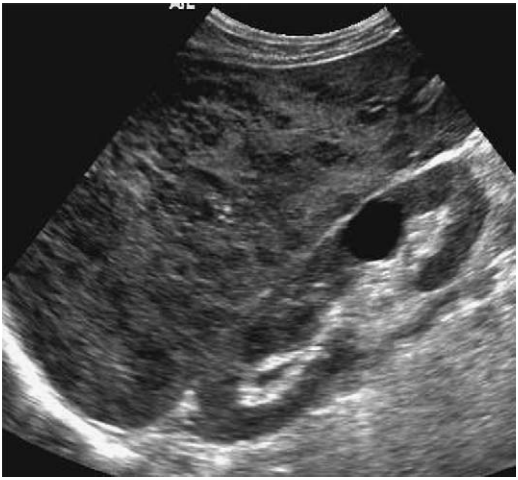

Fig. 9. Renal cyst. Longitudinal scan of right kidney demonstrates intraparenchymal, smooth-walled, fluid-filled structure. (Courtesy of D. Riley, MD, St. Luke's/Roosevelt Hospital, New York).

resulting from high-grade obstruction. The opposite kidney must be scanned to distinguish unilateral from bilateral hydronephrosis, which has a different differential diagnosis that usually is related to bladder outlet obstruction.

There are some common pitfalls in renal US when assessing for hydronephrosis. Specifically, false-negative scans are encountered when scanning a markedly dehydrated patient because the presence of hydronephrosis commonly is masked in the dehydrated patient [16,40]. False-positive findings are associated with conditions such as pregnancy, polycystic kidney disease (Fig. 10) [45], vesicoureteral reflux (Fig. 11) [45], and an overdistended bladder. These conditions can mimic bilateral hydronephrosis [16]. Overdistended bladders easily are avoided by having the patient void before evaluating renal architecture if possible.

Clinical algorithm for bedside emergency department renal ultrasound

Bedside EP-performed renal US is indicated in all patients presenting with flank pain who are suspected of having renal colic. The classic patient is the patient with flank pain and hematuria, but US can be performed on all patients presenting with flank pain. In addition, all patients presenting with urinary retention and bladder distention can benefit from bedside ED renal US that includes an assessment of bladder volume. Fig. 12 is an adapted clinical algorithm for patients with flank pain [16].

Summary

Renal US is one of several imaging modalities available to the EP in the evaluation of patients with acute urologic disorders. It offers excellent

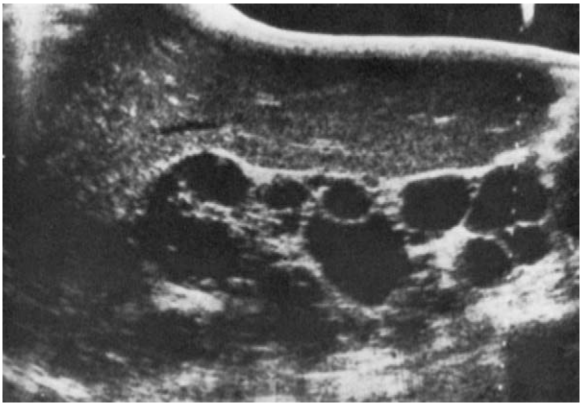

Fig. 10. Adult polycystic kidney disease. Longitudinal scan of right kidney demonstrates the classic appearance of multiple cysts of varying shape and size. (*From* Scheible W, Talner LB. Gray scale ultrasound and the GU tract. Radiol Clin N Am 1979;17:288; with permission.)

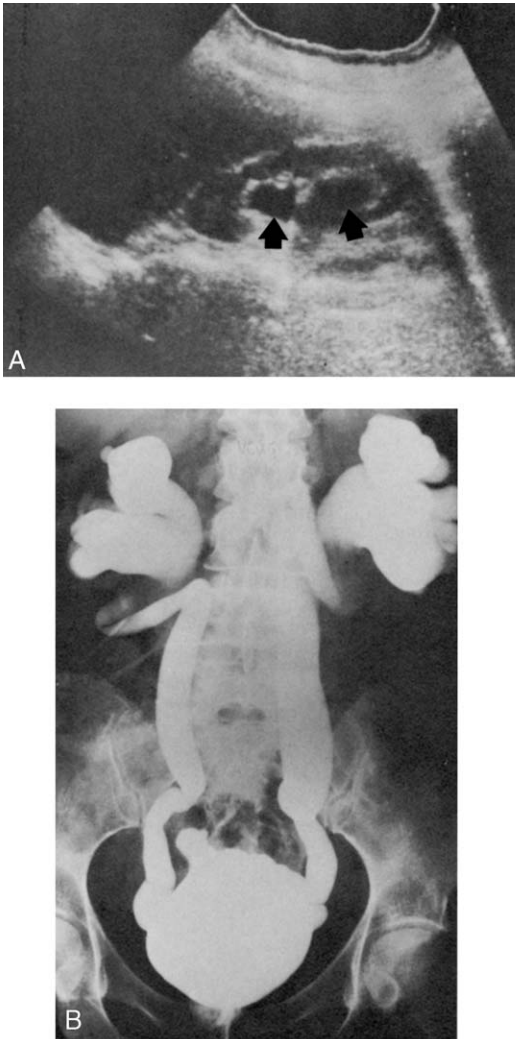

Fig. 11. Vesicoureteral reflux with ultrasound scan false-positive for obstructive hydronephrosis. (*A*) Longitudinal view of right kidney demonstrates dilated collecting system (*arrows*). (*B*) Cystogram reveals massive bilateral reflux as the cause of the collecting system dilatation. (*From* Amis ES, Hartman DS. Renal ultrasonography 1984: a practical overview. Radiol Clin N Am 1984;22:323; with permission.)

anatomic detail without exposure to radiation or contrast agents but is limited in its assessment of renal function. It is an important alternative to helical CT scanning for evaluating renal colic, especially in children and pregnant women. It has an important role in excluding bilateral renal obstruction as the cause of acute renal failure. It is likely that Doppler renal US also will take on a prominent role in the evaluation of renal vascular

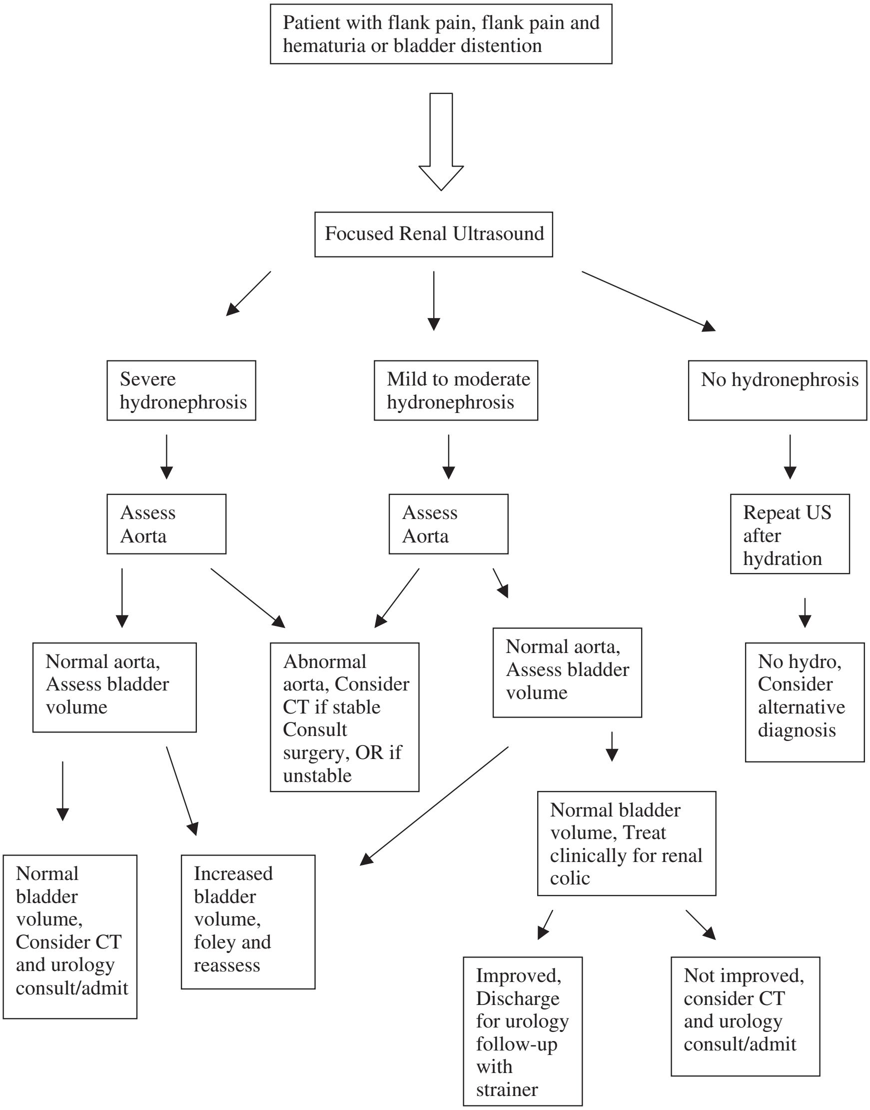

Fig. 12. Clinical algorithm for patients with flank pain. (*Adapted from* Swadron S, Mandavia DP. Renal ultrasound. In: Ma OJ, Mateer JR, editors. Emergency ultrasound. New York: McGraw Hill Professional; 2002; p. 199.)

disorders. It already has become the standard of care in the management of renal transplant patients [46]. Bedside emergency renal US performed and interpreted by EPs with limited training and experience is increasing in use and gaining acceptance. At present, the primary role of renal US is to identify hydronephrosis in patients with renal colic or acute renal failure but, in the future, its role likely will expand as technology advances and its use increases. In many patients, bedside renal US may obviate the need for further diagnostic workup and speed the diagnosis and treatment of an emergency patient.

References

[1] Gerlach AT, Pickworth KK. Contrast medium-induced nephrotoxicity: pathophysiology and prevention. Pharmacotherapy 2000;20:540–8.
[2] Waybill MM, Waybill PN. Contrast media-induced nephrotoxicity: identification of patients at risk and algorithms for prevention. J Vasc Interv Radiol 2001;12:3–9.
[3] Burge HJ, Middleton WD, McClennan BL, et al. Ureteral jets in healthy subjects and in patients with unilateral ureteral calculi: comparison with color Doppler US. Radiology 1991;180:437–42.
[4] Rosen P, Barkin R, Ling LJ. Emergency medicine: concepts and clinical practice. 4th edition. St. Louis (MO): Mosby; 1998.
[5] Chen MY, Zagoria RJ. Can noncontrast helical computed tomography replace intravenous urography for evaluation of patients with acute urinary tract colic? J Emerg Med 1999;17:299–303.
[6] Colistro R. Unenhanced helical CT in investigation of acute flank pain. Clin Radiol 2002; 57(6):435–41.
[7] Fielding JR, Steele G, Fox LA, et al. Spiral computerized tomography in the evaluation of acute flank pain: a replacement for excretory urography. J Urol 1997;157:2071–3.
[8] Fowler KA. US for detecting renal calculi with nonenhanced CT as a reference standard. Radiology 2002;222(1):109–13.
[9] Sheley RC, Semonsen KG, Quinn SF. Helical CT in the evaluation of renal colic. Am J Emerg Med 1999;17:279–82.
[10] Sheafor DH, Hertzberg BS, Freed KS, et al. Nonenhanced helical CT and US in the emergency evaluation of patients with renal colic: prospective comparison. Radiology 2000;217:792–7.
[11] Smith RC, Rosenfield AT, Kyuran AC. Acute flank pain: comparison of non-contrast enhanced CT and intravenous urography. Radiology 1995;194:789–94.
[12] Smith RC, Verga M, McCarthy S, et al. Diagnosis of acute flank pain: value of unenhanced helical CT. AJR Am J Roentgenol 1996;166:97–101.
[13] Swanson SK, Heilman RL, Eversman WG. Urinary tract stones in pregnancy. Surg Clin N Am 1995;75(1):123–42.
[14] Wong SK. Acute renal colic: value of unenhanced spiral CT compared with intravenous urography. Ann Acad Med Singapore 2001;30(6):568–72.
[15] Coleman BG. Ultrasonography of the upper genitourinary tract. Urol Clin N Am 1985;12: 633–44.
[16] Swadron S, Mandavia DP. Renal ultrasound. In: Ma OJ, Mateer JR, editors. Emergency ultrasound. New York: McGraw Hill Professional; 2002. pp. 197–220.
[17] Kiely EA, Hartnell GG, Gibson RN, et al. Measurement of bladder volume by real-time ultrasound. Br J Urol 1987;60:33–5.
[18] Sinclair D, Wilson S, Toi A, et al. The evaluation of suspected renal colic: ultrasound scan vs excretory urography. Ann Emerg Med 1989;18:556–9.
[19] Svedstrom E, Alanen A, Nurmi M. Radiologic diagnosis of renal colic: the role of plain films, excretory urography and sonography. Eur J Radiol 1990;11:180–3.
[20] Dalla Palma L, Stacul F, Bazzocchi M, et al. Ultrasonography and plain film versus intravenous urography in ureteral colic. Clin Radiol 1993;47:333–6.
[21] Smith SL. The role of the plain radiograph and renal tract ultrasound in the management of children with renal tract calculi. Clin Radiol 2000;55(9):708–10.

[22] Ireton RC, Krieger JN, Cardenas DD, et al. Bladder volume determination using a dedicated, portable ultrasound scanner. J Urol 1990;143:909–11.
[23] Mainprize TC, Drutz HP. Accuracy of total bladder volume and residual urine measurements: comparison between real-time ultrasound and catheterization. Am J Obstet Gynecol 1989;160:1013–6.
[24] Kawashima A. Radiologic evaluation of patients with renal infections. Infect Dis Clin N Am 2003;17(2):433–56.
[25] Allen HA, Walsh JW, Brewer WH, et al. Sonography of rmphysematous pyelonephritis. J Ultrasound Med 1984;3:533–7.
[26] Huang JJ, Tseng CC. Emphysematous pyelonephritis: clinicoradiological classification, management, prognosis and pathogenesis. Arch Intern Med 2000;160:797–805.
[27] Thurston W, Wilson S. The urinary tract. In: Rumack C, Wilson S, Charboneau J, editors. Diagnostic ultrasound. St. Louis (MO): Mosby; 1997. pp. 329–98.
[28] Williamson M. Renal ultrasound. In: Williamson M, editor. Essentials of ultrasound. Philadelphia: WB Saunders; 1996. pp. 562–79.
[29] Chan H. Noninvasive bladder volume measurement. J Neurosci Nurs 1993;25:309.
[30] Chang SD, Hricak H. Radiological evaluation of the urinary bladder, prostate and urethra. In: Grainger RG, Allison DJ, editors. Diagnostic radiology: a textbook of medical imaging. 4th edition. London: Churchill Livingstone; 2001. pp. 1615–52.
[31] Brenner BM, Rector FC. Renal vein thrombosis. In: Brenner BM, Rector FC, editors. The kidney. Philadelphia: WB Saunders; 2000.
[32] Mandavia DP, Pregerson B, Henderson SO. Ultrasonography of flank pain in the emergency department: renal cell carcinoma as a diagnostic concern. J Emerg Med 2000; 18:83–6.
[33] Smith SJ, Bosniak MA, Megibow AJ, et al. Renal cell carcinoma: earlier discovery and increased detection. Radiology 1989;170:699–703.
[34] Tosaka A, Ohya K, Yamada K, et al. Incidence and properties of renal masses and asymptomatic renal cell carcinoma detected by abdominal ultrasonography. J Urol 1990; 144:1097–9.
[35] Ueda T, Mihara Y. Incidental detection of renal carcinoma during radiological imaging. Br J Urol 1987;59:513–5.
[36] Lanoix R. A preliminary evaluation of emergency ultrasound in the setting of an emergency medicine training program. Am J Emerg Med 2000;18(1):41–5.
[37] Buchberger W, Penz T, Wicke K, et al. Diagnosis and staging of blunt kidney trauma. A comparison of urinalysis, IV urography, sonography and computed tomography. Rofo Fortschr Geb Rontgenstr Neuen Bildgeb Verfahr 1993;58:507.
[38] Furtschegger A, Egender G, Jaske G. The value of sonography in the diagnosis and follow-up of patients with blunt renal trauma. Br J Urol 1988;62:110–6.
[39] American College of Emergency Physicians. Policy statement: use of ultrasound imaging by emergency physicians. Ann Emerg Med 1997;30:364–5.
[40] Mandavia DP. Ultrasound training for emergency physicians—a prospective study. Acad Emerg Med 2000;7(9):1008–14.
[41] Rosen CL, Brown DFM, Sagarin MJ, et al. Ultrasonography by emergency physicians in patients with suspected ureteral colic. J Emerg Med 1998;16:865–70.
[42] Henderson SO, Hoffner RJ, Aragona JL, et al. Bedside emergency department ultrasonography plus radiography of the kidneys, ureters and bladder vs intravenous pyelography in the evaluation of suspected ureteral colic. Acad Emerg Med 1998;5(7): 666–71.
[43] Heller M, Jehle D. Primary applications of ultrasound. In: Heller M, Jehle D, editors. Ultrasound in emergency medicine. Philadelphia: WB Saunders; 1995. pp. 41–104.
[44] Brandt TD, Neiman HL, Dragowski MJ, et al. Ultrasound assessment of normal renal dimensions. J Ultrasound Med 1982;1:49.

[45] Amis ES, Cronan JJ, Pfister RC, et al. Ultrasonic inaccuracies in diagnosing renal obstruction. Urology 1982;19(1):101–5.
[46] O'Neill WC, Baumgarten DA. Sonography in transplantation: essential component of management of renal transplantation. Am J Kidney Dis 2002;39(4):663–78.
[47] Chang TS, Lepanto L. Ultrasonography in the emergency setting. Emerg Med Clin N Am 1992;10:1–25.
[48] Kellet MJ. The genitourinary tract. In: Grainger RG, Allison DJ, editors. Diagnostic radiology: a textbook of medical imaging. 4th edition. London: Churchill Livingstone; 2001. pp. 1489–96.
[49] Spencer BA, Wood BJ, Dretler SP. Helical CT and ureteral colic. Urol Clin N Am 2000;27: 231–41.
[50] Zubarev AV. Ultrasound of renal vessels. Eur Radiol 2001;11(10):1902–15.