Nonenhanced Helical CT and US in the Emergency Evaluation of Patients with Renal Colic: Prospective Comparison

PURPOSE: To compare nonenhanced helical computed tomography (CT) with ultrasonography (US) for the depiction of urolithiasis.

MATERIALS AND METHODS: During 9 months, 45 patients (mean age, 44 years; mean weight, 92.5 kg) prospectively underwent both nonenhanced helical CT (5-mm collimation; pitch of 1.5) and US of the kidneys, ureters, and bladder. US evaluation included a careful search for ureteral calculi. Presence of calculi and obstruction and incidental diagnoses were recorded. Clinical, surgical, and/or imaging follow-up data were obtained in all patients. The McNemar test was used to compare groups.

RESULTS: Diagnoses included 23 ureteral calculi and one each of renal cell carcinoma, appendicitis, ureteropelvic junction obstruction, renal subcapsular hematoma, cholelithiasis, medullary calcinosis, and myelolipoma. CT depicted 22 of 23 ureteral calculi (sensitivity, 96%). US depicted 14 of 23 ureteral calculi (sensitivity, 61%). Differences in sensitivity were statistically significant ($P = .02$). Specificity for each technique was 100%. When modalities were compared for the detection of any clinically relevant abnormality (eg, unilateral hydronephrosis and/or urolithiasis in patients with an obstructing calculus), sensitivities of US and CT increased to 92% and 100%, respectively. One case of appendicitis was missed at US, whereas medullary calcinosis and myelolipoma were missed at CT.

CONCLUSION: Nonenhanced CT has a higher sensitivity for the detection of ureteral calculi compared with US.
practices, however, the use of US for screening patients with acute renal colic is less widespread. In contrast, emergency department physicians are increasingly using US as a bedside screening examination. Indeed, findings in two recent studies (10,11) have suggested that US can be used effectively in screening for acute renal obstruction due to nephrolithiasis. While the use of US in the emergency department may be controversial, US is becoming more widely accepted due to its low cost and ready availability.

Results of previous studies (7) have shown a higher sensitivity and specificity with US compared with intravenous urography, but, to our knowledge, there are no studies in the radiology literature in which US and nonenhanced CT in screening for urolithiasis are directly compared.

Using state-of-the-art CT and US equipment and experienced sonographers, sonologists, and CT radiologists, we undertook a blinded prospective comparison of US and nonenhanced helical CT for the evaluation of patients with acute flank pain.

MATERIALS AND METHODS

During 9 months, 45 consecutive patients referred from our emergency department for evaluation of renal colic were prospectively enrolled into our study. Because of staffing limitations, only patients referred for imaging between the hours of 8 AM and 5 PM were eligible for inclusion. Three patients refused to enroll in the study protocol and thus were excluded from the study population. Of the 45 patients, 17 were women, and 28 were men. The mean patient age was 44 years (range, 19–68 years), and the mean patient weight was 92.5 kg (range, 54–145 kg). Of the 45 study patients, all had flank pain (unilateral \( n = 40 \) or bilateral \( n = 5 \)). Thirty-two (71\%) had hematuria. The study protocol was approved by our institutional review board. Each patient provided written informed consent before undergoing CT or US.

Nonenhanced helical CT followed by renal US was performed in 44 patients. In one patient, initial US was followed by helical CT. Both examinations were performed prospectively within 4 hours, without each clinician having a priori knowledge of the findings obtained at the comparison examination. Radiologists, sonologists, residents, and technical staff were prohibited from obtaining the results of the comparison examination until the patient was discharged from the department. All patients were hydrated with either intravenously or orally administered fluids, and both CT and US were performed with each patient having full bladder distention.

The CT protocol was as follows. All images were obtained with a helical CT scanner (HiSpeed Advantage; GE Medical Systems, Milwauk ee, Wis) without intravenous or oral administration of contrast medium. Images extended from the upper part of the abdomen (including the entire kidneys and adrenal glands) through the pubic symphysis, with the patient in the supine position. The section thickness and interval were 5 mm, with a pitch of 1.5:1. Images were obtained with a 0.8-second gantry rotation by using 140 kVp and 160–180 mAs. One of six attending radiologists (including D.H.S., K.S.F., M.T.K., E.K.P., R.C.N) experienced with CT reviewed the images from each examination before the patient was discharged from the CT suite. Additional scanning or reconstruction of images was requested by the attending radiologist when needed. CT room time, including image reconstruction and the attending radiologist’s review, averaged 10–15 minutes.

The US protocol was as follows. US was performed by using one of three US machines: Acuson XP-128 (Mountain View, Calif), Acuson XP-128/ART (Mountain View, Calif), and ATL 3000 (Advanced Technologies Laboratories, Bothell, Wash). Curved phased-array transducers (2–5 MHz) were used, with transducer frequencies selected to optimize imaging of the kidneys, ureters, and bladder. Each patient underwent standard renal US, including evaluation of the kidneys, ureters, and bladder, with hard-copy images obtained. The kidneys were evaluated completely in the longitudinal and transverse projections at real-time evaluation. At minimum, transverse images were obtained of the superior, middle, and inferior portions of each kidney and longitudinal images of the lateral, middle, and medial portions of each kidney. Additional images were obtained to document abnormalities when seen.

The bladder was also evaluated at real-time imaging, with a directed attempt made to image the ureterovesical junction bilaterally. Longitudinal and transverse images of the bladder were obtained. Real-time assessment also included a focused attempt to image the ureters. When depicted, both transverse and longitudinal images of the ureters were obtained. Up to 5 minutes of transverse color Doppler US of the bladder was performed to evaluate the presence of ureteral jets. Ureteral jets were considered abnormal when they were unilaterally absent, diminished, or continuous.

Of the 45 patients, 41 underwent Doppler US of the ureters. Each examination was performed by sonographers experienced in US of the urinary tract. One of eight attending radiologists (including D.H.S., B.S.H., K.S.F., B.A.C., E.K.P., R.C.N) experienced in US reviewed the images from each examination before the patient was discharged from the US room. The attending radiologist performed additional scanning when needed. All initial US examinations were performed in 30 minutes or less. However, 5–10 minutes of additional room time was often required for the attending radiologist’s image review or additional scanning.

Hard-copy images from the CT examinations were reviewed independently by two radiologists (M.T.K., K.S.F.) experienced in abdominal CT. Only soft-tissue windows identical to those used in our clinical practice were provided. Similarly, the sonograms were randomized and reviewed independently by two sonologists (B.A.C., B.S.H.) experienced in renal US. The sonologists were provided with a sonographer’s report completed at the time of US that included the sonographer’s findings and overall impression. All observers were blinded to patient diagnosis and findings obtained at the comparison examination. Images were interpreted for the presence, number, size, and location of calculus and for the presence of associated hydroureter and hydronephrosis. Incidental diagnoses were also recorded.

Once the observers completed their independent reviews, all cases in which there were disagreements about the presence of renal obstruction or ureteral calculus at CT were reevaluated, with differences resolved by consensus. A similar consensus evaluation was performed for cases with disagreements about the presence of renal obstruction or ureteral calculus at US. In cases with disagreement between observers, the consensus ratings were used for assessing diagnostic accuracy.

Four interpretations were available for CT and US observers, including the following: findings consistent with urolithiasis, equivocal or nondiagnostic findings, no evidence of urolithiasis, or unsuspected diagnosis (eg, appendicitis) responsible for the patient’s symptoms. For the assessment of diagnostic accuracy, a final diagnosis was determined by using a combination of calculus recovery (\( n = 5 \))...
Diagnoses included 23 ureteral calculi (Fig 1). One patient each had renal cell carcinoma, ureteropelvic junction obstruction, and renal subcapsular hematoma. Only one patient had a nonurologic (acute appendicitis) cause of acute flank pain identified at imaging (Fig 2). Additional findings included one patient each with renal medullary calcinosis, cholelithiasis, and adrenal myelolipoma. Of the remaining 15 patients in whom no abnormalities were identified at CT and US, final clinical diagnoses included musculoskeletal or disk-related pain (n = 5), gastroenteritis (n = 2), urinary tract infection or pelvic inflammatory disease (n = 3), nephrotic syndrome (n = 2), recent ureteral calculus passage (n = 1), prostatitis (n = 1), and gastroesophageal reflux (n = 1). Of the 23 calculi, six (26%) were located in the proximal ureter or ureteropelvic junction, three (13%) were located in the middle of the ureter, four (17%) were located in the distal ureter, and 10 (43%) were located at the ureterovesical junction. The mean calculus size was 4.4 mm (range, 2–15 mm). Of the 23 ureteral calculi, five (22%) were larger than 5 mm.

By consensus, the observers detected 22 of 23 calculi (sensitivity, 96%) at CT readings. By consensus, the observers detected 14 of 23 calculi (sensitivity, 61%) at US readings. Specificity for both modalities was 100%. In patients with ureteral calculi, there was a concurrence between CT and US findings in 13 (57%) of 23 cases (Fig 1). The Table summarizes calculus size and location, presence of ancillary findings, and detection with each modality in these 23 cases. The sensitivity of CT for the detection of ureteral calculi was statistically higher than that of US (P = .02). For individual observers, the sensitivity for the detection of ureteral calculi was 83%–91% for CT and 39%–61% for US. For individual observers, the specificity for the detection of ureteral calculi was 95% for CT and 100% for US.

When techniques were compared for the detection of clinically relevant abnormalities (eg, unilateral hydronephrosis or urolithiasis in a patient with an obstructing calculus, renal masses, or appendicitis), the sensitivity of consensus interpretation at US and CT increased from 61% to 85% and from 96% to 100%, respectively. Specificity remained 100% for both techniques. For individual observers, the sensitivity for detection of any clinically relevant abnormality was 96%–100% for CT. For individual sonologists, the sensitivity reached 77% for both observers. For individual observers, the specificity for the detection of any clinically relevant abnormality was 100% for both CT and US.

There was good agreement between observers in the diagnosis of ureteral calculi with CT, with a \( \kappa \) statistic of 0.82 (standard error, 0.085). Despite interobserver differences in sensitivity for the detection of ureteral calculi, there was still good overall observer agreement for US, with a \( \kappa \) statistic of 0.78 (standard error, 0.11). There was no statistical difference in the observer agreement for US
when compared with that of CT ($P = .21$).

At consensus readings, a single case of appendicitis was missed at US. Myelolipoma and medullary calcinosis were missed at CT. The myelolipoma was evident in retrospect, but owing to its high fat content and large size, it blended into the retroperitoneal fat at CT. The case of medullary calcinosis, while apparent at US, was only subtly apparent at CT, even in retrospect. There was only one false-negative CT scan for calculi. In this case, a 3-mm calculus in the left ureterovesical junction was missed at CT by both observers but was seen at US and was confirmed by means of calculus recovery (Fig 3). In three of the nine cases of missed calculi at US, no ancillary sign of acute obstruction (ie, hydronephrosis or unilateral abnormal ureteral jet) was depicted at US (Fig 4). Of the 23 patients with documented calculi, 15 (65%) had associated unilateral hydronephrosis. Ureteral jet analysis was performed in 19 of 23 patients with documented calculi. No false-positive findings would have resulted from the analysis of ureteral jets. However, in six cases with documented calculi, the ureteral jets were normal (Table).

**DISCUSSION**

Traditionally, suspected nephrolithiasis has been evaluated with intravenous urography. Recently, however, many practices have adopted nonenhanced helical CT as the imaging modality of choice for the detection of ureteral calculi and associated renal obstruction (1–4). Compared with those of intravenous urography, the benefits of nonenhanced CT include the following: no requirement for intravenously administered contrast material, high sensitivity for calculus detection, and ability to depict nonurinary causes of acute flank pain.

The exact sensitivity of intravenous urography for calculus detection is uncertain. However, in one study (1) of pa-
patients with obstruction documented at intravenous urography compared with that documented at nonenhanced CT, 58% of calculi were not depicted. By comparison, the sensitivity for nonenhanced CT reaches nearly 100% (4,5). In addition to correctly depicting ureteral calculi, nonenhanced CT depicts extra-urinary abnormalities in 10%–16% of cases (3,5). Accordingly, many centers now routinely use CT to screen patients who have acute flank pain or hematuria. Prior to the acceptance of helical CT, several investigators (6,12,13) hailed US as a good alternative to intravenous urography, with sensitivities of 95%–100% for the detection of urinary tract obstruction. However, other findings (7–9) suggest more modest US sensitivities of 37%–64% for calculus detection, with sensitivities of 74%–85% for the detection of acute obstruction. Despite likely having a lower sensitivity for calculus detection than CT, US requires no ionizing radiation and is the study of choice in pregnant patients (14). Given the ready availability of US units in emergency departments, the emergency medicine literature (10,11) also advocates the use of US as a screening examination in the initial assessment of flank pain. Henderson and colleagues (11) reported that US performed by an emergency department physician is 97% sensitive for the detection of "pathology consistent with nephro-ureterolithiasis," when compared with intravenous urography. Rosen et al (10) reported that bedside US evaluation performed by the emergency department physician to evaluate hydronephrosis is 72% sensitive and 73% specific for the prediction of nephrolithiasis, compared with intravenous urography or CT. To our knowledge, in only one article (15) in the radiology literature was the effectiveness of US compared with that of CT for the detection of upper urinary tract calculi and hydronephrosis. Remer et al (15) reported that CT is faster (15 minutes compared with 37 minutes of room time) and more cost-effective ($38 compared with $58 of direct technical cost) than US after extracorporeal shock wave lithotripsy. Preliminary analysis of their data suggests a similar sensitivity in the detection of retained calculi fragments for combined US and conventional radiography compared with nonenhanced CT. However, their CT protocol neither included an evaluation of the distal ureters nor specifically addressed detection of urolithiasis. To our knowledge, no studies in the radiology literature have been conducted to directly compare the efficacy of US and CT in patients with acute renal colic.

In our study, the sensitivity of US (61%) for direct depiction of ureteral calculi was significantly lower than that of CT (96%); these findings approximate sensitivities reported in the literature (4,5,7–9). The greatest weakness of US is its inability to depict the entire ureteral course. Bowel gas and large patient habitus contribute to poor ureteral depiction. The majority of calculi not depicted at US in our study, however, were not in the middle of the ureter. In fact, many were 2–3 mm and were located at the ureteropelvic junction. Some authors (16–18) have advocated the use of transvaginal or transperineal US for improved calculus detection. While this approach is intuitive in the examination of women, it changes a relatively short examination into a longer, more expensive, and personally invasive procedure for the patient.

Another approach to improving US sensitivity is the use of color flow analysis of ureteral jets (19). However, a unilaterally abnormal ureteral jet usually can be suggestive of a ureteral calculus, but US cannot definitively depict the location of the obstructing lesion. Further, the finding of normal ureteral jets cannot be used to exclude a diagnosis of ureterolithiasis, since seven (30%) of 23 of our patients with documented calculi had normal ureteral jets. We achieved calculus detection sensitivities similar to those in other articles, although there was a relatively high prevalence of small ureteral calculi in our relatively overweight patient population (mean weight, 92.5 kg). These comparable sensitivities were achieved despite the fact that most prior studies (6,9,13) combined abdominal radiography and US, potentially allowing a more targeted US examination. At our institution, preprocedural abdominal radiographs are not routinely obtained because of their low yield and nonspecificity (13). Further, this combination has been shown (15) to be less cost-effective than CT in the detection of complications after extracorporeal shock wave lithotripsy.

There are additional limitations to this study that should be discussed. First, consensus readings at US or CT are not readily achievable in radiologic practice. This is of particular importance since the sensitivity of US was as low as 39% for...
individual readers. While the $k$ statistic suggested good agreement between sonologists, this was largely due to agreement on the negative studies.

Second, there were relatively few (1 [2%] of 45 patients) nonurinary diagnoses in our study population. Previous investigators (3,5) have reported nonurinary diagnoses in up to 16% of cases. The lack of nonurologic abnormalities could result in an overestimation of the ability of US to depict clinically correct diagnoses. The relatively low prevalence of these abnormalities in our patient population may have resulted from accurate patient triage by the referring emergency department physicians.

Third, our study did not include routine evaluation of renal resistive indexes. In the patients without hydronephrosis or calculi identified at US, asymmetric changes in the resistive indexes might have been suggestive of early obstruction, improving overall sensitivity (9,20,21). However, we estimated that the addition of Doppler indexes would have required an additional 15–20 minutes of room time per patient. This additional time would increase the cost of the examination and would result in an unacceptably long room time compared with that of nonenhanced CT. While we limited US time in our study, CT still required substantially less time, particularly if the time required for hydrating patients prior to US also is considered.

Finally, to evaluate US on the basis of whether a correct clinical diagnosis could be made without regard to accuracy in the depiction of urolithiasis is somewhat artificial. However, prior investigators have considered unilateral hydronephrosis in the setting of acute flank pain as presumptive evidence of nephrolithiasis. Certainly, when there is a high clinical suspicion for calculus disease and when US shows hydronephrosis, conservative treatment (ie, hydration and analgesia) of the presumed nephrolithiasis could be initiated. Nevertheless, the additional knowledge of calculus size and location afforded by a CT image can be helpful in making prospective patient care decisions. In addition, when US shows no abnormality in a symptomatic patient, further investigation (usually CT) is warranted to identify the cause of the patient’s pain. In our study, if US had been the primary screening modality, up to 32 (71%) of 45 patients could have required subsequent CT, which would limit the cost-effectiveness of US.

In conclusion, nonenhanced helical CT has a higher sensitivity for the detection of ureteral calculi, compared with US. The sensitivity of US for the detection of only ureteral calculi was 39%–61%. Predictably, when we considered ancillary findings, the overall sensitivity of US improved. Nevertheless, since a substantial proportion of patients with positive and negative results at US will require CT, we recommend nonenhanced CT as the imaging study of choice in the evaluation of patients with acute flank pain, and we reserve US for pediatric and pregnant patients to avoid the risks of radiation.

References