Imaging in the Management of Ureteral Calculi*

Learning Objective: At the conclusion of this continuing medical education activity, the participant will be able to discuss the currently accepted recommendations for imaging ureteral calculi in the settings of initial diagnosis, observation of known calculi and follow-up after either spontaneous passage or definitive treatment, as well as understand the evidence-based rationale for these recommendations.

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*This AUA Update addresses the Core Curriculum topics of Urolithiasis and Uroradiology.
Key Words: ureteral calculi, epidemiology, imaging

OVERVIEW

Urolithiasis is a common problem worldwide, and has been associated with an increase in incidence and prevalence during the last 25 years. Patients diagnosed with upper urinary tract stones, particularly ureteral calculi, often undergo repeated imaging studies during the management and treatment of the disease. The risk of excessive cumulative radiation exposure, coupled with cost concerns, has prompted efforts to standardize the use of imaging studies in the management of ureteral calculi. We review the evidence and recommendations for the type and frequency of imaging as it pertains to the diagnosis, management and follow-up of ureteral calculi with special emphasis on the AUA clinical effectiveness protocols for imaging in the management of ureteral calculus disease.2

Epidemiology

Kidney stone disease in the U.S. has demonstrated a linear increase in prevalence during the last several decades. An assessment of the NHANES (National Health and Nutrition Examination Survey) II and III datasets suggested that the lifetime risk of forming stones for U.S. adults increased significantly from 3.2% in 1976 to 1980 to 5.2% in 1988 to 1994.3 The most recent NHANES data (2007 to 2010) indicate that this trend has persisted, with a current estimated prevalence of stone disease in U.S. adults of 8.8%.4 A literature review that included data from 5 European countries, Japan and the United States suggested that increases in the incidence and prevalence of stone disease are global phenomena that have been attributed in part to global warming and changes in dietary habits.1 Consequently, imaging studies obtained for the diagnosis and management of urinary calculi are likewise on the rise. With a recurrence rate of 26% to 53%,5,6 a first stone former is likely to be subjected to numerous imaging studies throughout his or her lifetime.

Furthermore, there has been a trend toward increased use of modalities associated with higher radiation exposure for the evaluation of acute flank pain. Hyams et al used the National Hospital and Ambulatory Care Survey dataset from 2005 to 2009 to analyze trends in emergency room evaluations for acute flank pain and found a significant increase in CT use (p <0.0001) and a decrease in conventional x-ray use (p=0.035), with stable ultrasound use during this time.7 Likewise, analysis of data from the Centers for Medicare and Medicaid Services revealed a 31% decrease in the use of IVU and a threefold increase in the use of non-contrast CT for the diagnosis of urolithiasis between 1992 and 1998.8 That trend has continued, with a 1.8-fold increase in CT use between 2002 and 2007 among Medicare beneficiaries for evaluation of urinary tract stones.9

Considerations When Choosing an Imaging Modality

Sensitivity and specificity: The sensitivity and specificity of different imaging modalities are of paramount importance when establishing utility in the diagnosis of ureteral calculi. As shown in table 1, a ‘‘standard’’ protocol NCCT has the highest median sensitivity and specificity (98% and 97%, respectively) of all conventional imaging modalities for detecting ureteral calculi. However, a low dose protocol CT, typically one that is associated with ≤4 mSv, sacrifices little in the way of sensitivity or specificity in the detection of ureteral stones (97% sensitivity and 95% specificity). Regardless, the diagnostic success of an imaging modality must be weighed against its potentially adverse effects, notably radiation exposure and cost.

Radiation exposure: ‘‘Effective radiation dose’’ (mSv), the sum of the equivalent doses of radiation to exposed organs, is used to quantify the potential adverse biological effects of radiation on patients and health care providers. The effective dose does not equate to the absorbed dose for an individual, as that measure is dependent upon the scanning protocol for the study and the specific equipment used. Table 2 shows the estimated effective doses associated with conventional imaging techniques. Of note a low dose protocol CT has the same estimated effective dose as an IVU and less than a third the effective dose of a standard protocol CT.2

The concept of ALARA (As Low as Reasonably Achievable), originally promulgated in pediatric radiology, represents an effort to minimize the total radiation exposure to a patient through modifications in machine design (exposure rate and exposure/image) and machine operation (fluoroscopy time and

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<th>Table 1. Sensitivity and specificity of conventional imaging modalities for the detection of ureteral calculi</th>
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ABBREVIATIONS: BMI (body mass index), CT (computerized tomography), IVU (intravenous urography), KUB (plain film of the kidneys, ureters and bladder), MRI (magnetic resonance imaging), NCCT (non-contrast CT), SSD (skin-to-stone distance), SWL (shock wave lithotripsy), URS (ureteroscopy)
number of images). The need for ALARA is highlighted by several recent retrospective reviews that quantified the radiation exposure associated with a single stone event.

Ferrandino et al performed a multicenter, retrospective review of 108 first time stone formers to determine the radiation exposure associated with an acute stone event through 1 year of follow-up. Although the median effective radiation dose per patient was 29.7 mSv, notably 20% of patients received greater than 50 mSv of radiation, the maximum recommended yearly dose for occupational exposure set by the International Commission on Radiological Protection.

In a retrospective review of 60 patients presenting with renal and/or ureteral calculi ultimately treated either conservatively or with surgical intervention, John et al determined the radiation exposure associated with a single stone episode from the time of diagnosis to when the patient was deemed stone-free. The median effective radiation dose per patient was 5.3 mSv. Radiation exposure was highest for renal calculi, followed by middle and distal ureteral calculi. The 14 patients who underwent CT imaging during this time had a significantly higher median effective radiation dose than those not imaged with CT (14.46 mSv vs 4.25 mSv, respectively, p <0.0001).

Finally, Fahmy et al analyzed the charts of 104 patients followed for 2 years from the time of an acute stone episode. During the first year of follow-up the median effective dose per patient was 29.29 mSv, decreasing significantly to 8.04 mSv in the second year (p <0.01) by performing less CT imaging and more ultrasonography. Although the radiation exposure in 17.3% of patients exceeded 50 mSv within the first year, this threshold was not exceeded in any patient during year 2 of follow-up.

Cost: The diagnosis and management of urolithiasis significantly impact the economics of health care through direct and indirect costs. In 2000 the total annual expenditure for urolithiasis was estimated at $2.1 billion including $971 million for inpatient services, $607 million for physician office and hospital outpatient services, and $490 million for emergency room services. Included in this expenditure are costs associated with imaging which, according to the Medicare Payment Advisory commission, account for 16% of the total cost incurred during a single stone episode. The exact cost of each imaging technique varies greatly, and is dependent on market-driven factors and the source of the payer. According to national averages of Centers for Medicare and Medicaid Services charge data for 2012, if a KUB has a relative value of 1 the average allowable charge is $5 for an ultrasound or IVU, $10 for CT and 30 for magnetic resonance imaging. While this information provides only a relative measure of cost, it demonstrates that advanced imaging techniques such as CT and MRI are associated with substantially higher cost than basic imaging modalities such as plain radiography or ultrasound.

PROGNOSTIC INFORMATION

In addition to the simple detection of stones, imaging can provide other useful information about stone and patient characteristics which can be used to guide management and treatment decisions.

Size and location: Hübner et al performed a meta-analysis of 6 natural history studies of stones comprising 2704 patients who underwent observation for ureteral calculi. The incidence of spontaneous stone passage varied according to the location of the stone in the ureter at initial presentation, with passage rates increasing the more distal the stone was located in the ureter (12%, 22% and 45% for stones in the proximal, middle and distal ureter, respectively).

Miller and Kane prospectively followed 75 patients with ureteral calculi, most of which were <4 mm, to determine the natural history of these stones. They found that 83% of ureteral stones passed without the need for intervention, with an average time to passage for stones ≤2 mm, 2.1 to 3.9 mm and ≥4 mm of 8.2, 12.2 and 22.1 days, respectively. Furthermore, of stones ≤6 mm that passed spontaneously 95% did so within 6 weeks of initial presentation. Eisner et al retrospectively reviewed the CT scans of patients presenting with obstructing ureteral calculi, and proximal ureteral stones had a significantly longer coronal diameter than distal ureteral stones (9.9 mm vs 8.3 mm, respectively, p=0.005) and were associated with significantly more ureteral dilatation (6.1 mm vs 5.3 mm, respectively, p=0.01).

While these studies demonstrate that size and location are important predictors of spontaneous stone passage, it is important to note that stone size may not be accurately measured in all dimensions on CT. Several studies have compared the transverse and longitudinal measurements of stones on CT and plain radiography and, although the transverse diameters were comparable on the 2 imaging modalities, CT overestimated the longitudinal (cephalocaudal) size of stones by 0.8 to 1.4 mm. Post-processing CT parameters can be optimized to increase the accuracy of stone measurement. Eisner et al used calipers to measure the diameter of 24 human stones and then embedded the stones in potatoes the size of human kidneys before imaging them with a 64 slice multidetector CT. In an in vivo correlate of the study, they measured the size of 41 spontaneously passed stones in patients diagnosed with distal ureteral calculi by CT. In the in vitro and in vivo studies the smallest discrepancy between stone size on imaging and actual stone size occurred when the stone was measured in a 4.0x magnified bone window. Therefore, while size and location can serve as general guides upon which to advise patients of the likelihood of spontaneous stone passage, stone size is best determined in the magnified bone window of a CT image.

Stone composition: Knowledge of current or prior stone composition is useful when advising patients on appropriate therapy, as stone composition is an indicator of stone fragility, an important determinant of shock wave lithotripsy success. Additionally, stone composition can determine if dissolution therapy is a reasonable therapeutic option, as for uric acid and some cystine stones.

Several investigators have attempted to correlate CT attenuation coefficient (HU) with stone composition, although this has been only marginally successful because of significant overlap in the range of HUs for each stone type. However, several studies have demonstrated an inverse relationship between CT attenuation coefficient and shock wave lithotripsy success, allowing this parameter to be used as a measure to identify patients who might be successfully treated with SWL and those better served with endoscopic management. Dual energy CT, on the other hand, may hold greater promise in determining actual stone composition compared to single source CT.

Skin-to-stone distance: Pareek et al introduced another important prognostic imaging parameter, skin-to-stone distance, which is obtained by averaging the distance from the skin to the stone at 0°, 45° and 90°. Wiesenthal et al conducted a retrospective review
of 204 patients with a solitary renal or ureteral calculus on CT treated with SWL. Using univariate and multivariate analyses to determine the influence of mean stone density and SSD on SWL success, they found that HU >900 (OR 0.49, 95% CI 0.32 to 0.75, p = 0.01) and SSD ≥9.2 cm (OR 0.49, 95% CI 0.31 to 0.78, p < 0.01) were the best independent predictors of SWL failure. Of note these same authors developed a nomogram to predict SWL outcomes for renal and ureteral calculi and determined that SSD was an independent predictor of SWL success for renal calculi while mean stone density was not. For ureteral calculi neither of these parameters was a predictor of SWL success, although body mass index, which likely correlates with SSD, was a negative predictor.

Ng et al performed logistic regression analysis to identify factors predictive of SWL success or failure. Using data from 94 patients with proximal ureteral stones treated with SWL, they determined that stone volume and mean stone density were independent predictors of SWL outcomes, while SSD showed only a minimal effect. Cut points for each parameter were determined using ROC curves and a scoring system was constructed based on stone volume >0.2 cc, mean stone density <593 HU and SSD <9.2 cm representing favorable parameters for SWL. For patients with 0, 1, 2 and 3 factors the stone-free rates were 17.9%, 48.4%, 73.3% and 100%, respectively. While these and other authors have shown that SSD is a useful prognostic indicator, others have not supported this conclusion.

**Urinary obstruction**: For patients with ureteral stones, CT may demonstrate secondary signs of obstruction including hydrourter in 82.7%, hydrenephrosis in 80%, periureteral edema in 59% and unilateral renal enlargement in 57.2%. However, these findings, particularly hydrenephrosis, have not been shown to be reliable predictors of the degree of obstruction.

Bird et al reviewed the records of 77 patients seen in the emergency department with renal colic who were diagnosed with ureteral stones by CT and who then underwent a diuretic 99mtechnetium mercaptoacetyltriglycine renal scan within a mean of 6 hours. In an attempt to correlate CT findings, such as renal parenchymal edema, hydrenephrosis, stranding and urinary extravasation, with the degree of obstruction seen on renal scan they found no difference in the number of secondary CT findings among those with high grade, partial and no obstruction but they did find a greater number of secondary CT findings in those with any obstruction vs no obstruction. Of note, no CT findings distinguished high grade from partial obstruction and only perinephric periureteral fat stranding distinguished any obstruction from no obstruction.

These results suggest that CT can identify the presence but not the degree of obstruction and, therefore, it may not be the best tool with which to determine the duration of time that a ureteral stone can be safely observed. With limited availability of IVU and renography, in the acute setting or at all, hydrenephrosis on CT or ultrasound is still the most commonly used finding to determine the need for and timing of intervention. However, for the conservative treatment of ureteral calculi, a follow-up functional study (IVU, diuretic renogram or CT urogram) may be advisable if prolonged observation is entertained.

**IMAGING MODALITIES**

**Computerized tomography**: NCCT is the gold standard imaging modality for the initial evaluation of a patient with abdominal pain and a suspected ureteral stone. CT is associated with high sensitivity and specificity for the diagnosis of ureteral stones (table 1). Prior to the widespread availability of CT, IVU constituted the gold standard for the diagnosis of ureteral stones. CT and IVU are equally effective at demonstrating the presence or absence of ureteral obstruction but CT is more accurate than IVU in precisely identifying a ureteral stone.

CT provides information about the surrounding viscera as well, which can be useful when attempting to identify the source of abdominal, pelvic or flank pain. Hopp et al reviewed the records of 1500 patients who underwent CT for acute flank pain and 69% had urolithiasis but an additional diagnosis was identified in 47%. A total of 24% of patients had a diagnosis other than stones and 14% required immediate or deferred attention for the diagnosis. The information garnered from CT, including stone size and location, stone density, SSD and presence of secondary signs of obstruction, is important for prognostic indicators that can be used when making recommendations for the management and particularly surgical treatment of stones. Furthermore, visualization of organs outside the genitourinary tract can provide information necessary to correctly diagnose the etiology of flank and/or abdominal pain.

**Ultrasound**: The main advantage of ultrasound is that it is associated with no ionizing radiation but this benefit comes at the expense of lower sensitivity for the detection of ureteral stones compared to other imaging modalities (table 1). Viprakasit et al compared ultrasound and CT for sensitivity, specificity and accuracy in detecting urinary stones. Sensitivity for the identification of a stone on ultrasound decreased as stone size decreased (sensitivity 35% for stones ≤4 mm and 86% for those ≥10 mm) and was lower for ureteral compared to renal stones (sensitivity 15% for ureteral and 44% for renal stones). However, evaluation of ureteral stones improved to 67% with the use of secondary characteristics such as hydrenephrosis or absence of ureteral jets.

While the sensitivity of ultrasound for detecting ureteral stones in general is moderate at best, this modality has its greatest effectiveness in diagnosing distal ureteral stones. Moesbergen et al followed 152 patients initially diagnosed with an impacted ureteral stone by CT (81% had a distal ureteral or ureterovesical stone) with concurrent CT and ultrasound examinations. The sensitivity and specificity of ultrasound for diagnosing persistent distal ureteral calculi during follow-up using CT as the reference was 94.3% and 99.1%, respectively. Furthermore, distal ureteral stones within 35 mm of the ureterovesical junction could be reliably followed on ultrasound. The authors concluded that findings on ultrasound indicative of a stone included a hyperechoic intraureteral focus with posterior acoustic shadowing, a circumferential anechoic rim of urine (halo sign) and random color encoding seen with color Doppler imaging in the area where shadowing would be expected (the twinkling artifact). Other investigators have reported greater sensitivity of color Doppler (97%) in detecting stones compared to gray scale technique (66%).

Implementation of color Doppler ultrasound imaging can also aid in the diagnosis of ureteral obstruction through assessment of the resistive index and identification of ureteral jets. Shokeir and Abdulmaaboud evaluated 109 patients who presented with unilateral flank pain and underwent CT, Doppler ultrasound and IVU. Compared to IVU, the predetermined gold standard, the sensitivity and specificity for detecting ureteral obstruction was 96% and 96%, respectively, for CT, and 90% and 100%,
respectively, for ultrasound. Others have defined a resistive index of 0.7 and a difference in resistive index between kidneys of 10% as diagnostic of obstruction.  

Ultrasound affords the opportunity to assess other viscera, albeit in a more limited fashion than CT or MRI. The sensitivity of ultrasound in diagnosing other causes of abdominal pain, such as appendicitis, has been reported to be as high as 85%. However, the lower sensitivity of ultrasound in diagnosing small stones (<4 mm), overestimation of stone size and limited use in obese patients reduce its overall usefulness in the management of acute flank pain.  

**Intravenous urography:** IVU has been largely supplanted by NCCT as the imaging modality of choice for the evaluation of acute flank pain because CT has greater sensitivity for detecting ureteral calculi (table 1), more rapid acquisition time and the potential to diagnose non-urinary causes for pain. However, the use of intravenous contrast with IVU provides functional information, qualitatively assesses renal obstruction and delineates the anatomy of the collecting system, which can be valuable in preoperative planning.  

**Plain radiography:** The sensitivity and specificity of plain abdominal radiographs for the detection of ureteral calculi are considerably lower than the other available imaging modalities (table 1). Inclusion of tomography with plain radiography increases the detection rate of urolithiasis. However, the effective radiation dose of a KUB and 3 tomograms is nearly 4 mSv, equaling or exceeding the dose associated with low dose CT (table 2).  

The radiopacity of a stone on plain film has potential implications for surgical management and follow-up. In most cases ureteral stones are initially diagnosed by CT. The CT scout image, which mimics a plain abdominal radiograph, may demonstrate a ureteral stone but is not as sensitive as either CT or KUB. Approximately 53% of stones visible on CT are not visible on CT scout. Furthermore, a stone not visible on CT scout can be seen on KUB in 10% to 43.5% of cases, and nearly all stones visible on CT scout can be visualized on KUB. Therefore, if a stone is visible on CT scout, it can be reliably followed by KUB imaging. However, if the stone is not visible on CT scout, a KUB should be obtained as this will determine whether KUB is sufficient for follow-up or if repeat CT is necessary. The combination of KUB and ultrasound has sensitivity and specificity for ureteral calculus detection that exceeds 90%.  

**Magnetic resonance imaging:** MRI has limited use in the management of ureteral calculi, in part because calculus cannot be directly visualized. However, MRI can diagnose urinary tract obstruction and pathology outside the genitourinary tract. For patients in whom radiation exposure must be avoided and ultrasonography proves non-diagnostic, as is often the case in pregnancy, MRI may have diagnostic benefit.  

Historically the use of T2-weighted MRI was thought to reasonably recognize ureteral stones and obstruction, as urine is readily identified during this phase and a filling defect and/or hydroureteronephrosis can indirectly diagnose an obstructing stone. Additionally, novel techniques applied to standard MRI, such as 3D FLASH and HASTE MR urography, demonstrate augmented sensitivity and specificity compared to standard MRI or CT and have been advocated for use in pregnancy.

**AUA CLINICAL EFFECTIVENESS PROTOCOL**

As the prevalence of urolithiasis, a disease known for its propensity for recurrence, continues to increase, standardization of management strategies becomes increasingly important to improve outcomes, minimize adverse effects and reduce the economic burden of the disease. While the European Association of Urology and the AUA have established guidelines addressing the management of ureteral calculi, these guidelines focus on treatment strategies and notably exclude recommendations directed at the type and frequency of imaging studies to use in the diagnosis, management and follow-up of ureteral stones. This void prompted the AUA to develop a clinical effectiveness protocol regarding the role of imaging in the management of ureteral calculi.

**Adults, initial presentation:** For adults presenting with flank and/or abdominal pain suggestive of renal colic, the goals are expeditious, accurate diagnosis and prompt disposition. Consequently, NCCT of the abdominal pelvis is recommended because of its high sensitivity and specificity for detecting ureteral stones, rapid image acquisition time and the widespread availability of CT scanners.

While standard NCCT of the abdomen and pelvis has the highest sensitivity and specificity for the detection of urolithiasis, low dose NCCT (≤4 mSv) can provide acceptable diagnostic accuracy with a significantly lower effective radiation dose. In their meta-analysis of published series from 1995 to 2007 Niemann et al found that the pooled sensitivity and specificity of low dose NCCT (<3 mSv) in the diagnosis of urolithiasis was 96.6% and 94.9%, respectively. Additionally, no difference between low dose and standard NCCT has been reported in the measurements of other important parameters gleaned from CT including stone size, HU and SSD.

However, low dose NCCT has shown limited usefulness in the evaluation of obese patients. The sensitivity and specificity of low dose NCCT for the detection of ureteral calculi are considerably lower in patients with BMI >30 kg/m² than in those with an index ≤30. As such, AUA recommends the use of low dose NCCT of the abdomen and pelvis for the diagnosis of ureteral calculi in patients with a BMI ≤30 kg/m² and standard protocol NCCT for those with a BMI >30 kg/m² (fig. 1).

It is also important at initial diagnosis to determine if the ureteral stone is radiopaque on KUB as this will impact recommendations for follow-up imaging. If the stone is visible on CT scout and/or KUB, follow-up imaging with a KUB should suffice. Oblique films may further enhance the ability to identify a ureteral calculus not seen on anteroposterior views. However, when the stone is not identifiable on KUB with or without oblique views, CT limited to the region of interest (eg pelvic CT for a distal ureteral calculus) should be judiciously obtained for follow-up.

**Adults, observation of known calculi/calculi:** Imaging in the setting of follow-up of a known ureteral calculus should convey information regarding the progression of a stone along the ureter and the presence of new or persistent hydrenephrosis. According to the AUA guidelines for the management of ureteral calculi, medical expulsive therapy should be considered for patients with a ureteral stone <10 mm and minimal hydronephrosis, no evidence of renal damage and well controlled pain symptoms. Figure 2 depicts the follow-up imaging algorithm for patients undergoing observation with or without medical expulsive therapy, beginning with determination of whether the stone is radiopaque as this charac-
Algorithm for imaging of suspected ureteral calculi at initial presentation

1. For a radiopaque stone, KUB and ultrasound provide the best combination of acceptable sensitivity and specificity, and minimal radiation exposure and cost to follow the progression of the stone. If a patient remains symptomatic despite negative KUB and ultrasound, then supplemental imaging such as oblique views and/or limited low dose NCCT (if BMI is ≤ 30 kg/m²) may identify a persistent stone.

2. If a patient has a radiolucent stone, then the follow-up algorithm begins with low dose NCCT of the abdomen and pelvis at a reasonable interval if the stone has not obviously passed. Imaging is repeated until documented passage of the stone or need for surgical intervention is apparent. No further imaging is necessary for a patient with either a radiolucent or radiopaque stone who reports relief of symptoms and passage of the stone (stone in hand). However, if an asymptomatic patient does not have evidence of stone passage, low dose NCCT of the abdomen and pelvis is recommended (fig. 2).

3. The interval(s) at which follow-up imaging should be performed after the diagnosis of a ureteral calculus is not explicitly stated in the imaging protocol because of a lack of definitive information in the literature regarding the duration of obstruction before the onset of irreversible loss of renal function. Consequently, it is left to the discretion of the practitioner to decide when to intervene surgically and when to continue to observe. However, a functional imaging study should be considered in a patient with hydroureteronephrosis who undergoes observation for an extended time. Furthermore, the majority of stones that will pass spontaneously do so within 6 weeks of diagnosis and, therefore, observation beyond 6 weeks is discouraged.

4. **Adults, follow-up after definitive treatment:** Follow-up imaging after surgical management of ureteral calculi is aimed at documenting the absence of the stone and resolution of obstruction. In the setting of URS postoperative hydronephrosis is likely a consequence of an obstructing retained ureteral stone/fragment, transient ureteral edema or ureteral stricture. The incidence of stricture after URS has been reported as 1% to 4%, but alarmingly, obstruction does not always cause symptoms. Although postoperative stricture formation after SWL is highly uncommon, postoperative imaging in this setting is important to confirm stone clearance and resolution of hydronephrosis.

5. Despite the general consensus regarding the need for imaging studies that identify residual stones following procedures that are associated with stone fragmentation (SWL and URS with stone fragmentation), the need for imaging that identifies hydronephrosis after URS and SWL is controversial. Although the incidence of postoperative stricture is low after URS and SWL, postoperative obstruction is not reliably associated with symptoms. Silent obstruction following URS has been reported with an incidence of 0% to 4.8%, compelling some investigators to advocate the use of routine imaging following URS. On the other hand, some studies have found that silent obstruction after URS is exceedingly rare and that nearly all cases of obstruction can be identified by selectively imaging patients at high risk (those with ureteral injury or an impacted stone, or those experiencing postoperative pain).
Figure 2. Algorithm for imaging during observation of known ureteral calculi

Figure 3. Algorithm for imaging of ureteral calculi after SWL and stone passage
Routine imaging of all patients after URS necessitates imaging of many patients unnecessarily. However, Manger et al reviewed the records of 289 patients who underwent URS with ultrasound follow-up and 4.8% had silent obstruction. According to their data, only 18 asymptomatic patients need to be imaged to diagnose 1 case of silent obstruction. Sutherland et al compared the economic consequences of routine postoperative imaging for all patients treated with URS versus selective imaging of symptomatic patients, taking into account the cost of imaging and the cost of complications associated with unrecognized loss of renal function, such as the need for dialysis or transplantation and the consequences of chronic kidney disease. Assuming a silent obstruction rate of 2% averaged from the literature, they calculated that selective postoperative imaging is associated with a $130 cost savings per patient compared to routine postoperative imaging in all patients after URS. However, a strategy of selective imaging could lead to the loss of 2 kidneys.
for every 100 patients undergoing URS. Sutherland et al concluded that this small cost savings is not worth the potential loss of renal function and associated sequelae, and they advocated routine imaging in all patients as recommended in the AUA protocol.

In an effort to balance diagnostic accuracy against radiation and cost concerns, the recommendations for imaging after URS, SWL and medical expulsive therapy are shown in figures 3 and 4. For a patient with a radiopaque ureteral calculus who undergoes SWL, KUB and ultrasound are sufficient to assess for the presence of residual fragments and hydronephrosis at follow-up. If the stone is radiolucent, ultrasound alone is initially sufficient but if hydronephrosis is evident, low dose NCCT of the abdomen and pelvis should be obtained to identify residual stone (fig. 3). Persistent symptoms following presumed successful medical expulsive therapy or spontaneous stone passage should initially be evaluated with ultrasound but if hydronephrosis is demonstrated, CT of the abdomen and pelvis with and without contrast should be obtained to assess for an additional stone or edema as the cause for persistent obstruction (fig. 3).

A distinction is made between URS with intact removal of a stone (fig. 4, A) and URS with fragmentation (fig. 4, B). Renal ultrasound is recommended after intact removal of a stone in an asymptomatic patient to ensure that there is no residual obstruction. If the patient is symptomatic postoperatively or has unexplained hydronephrosis on renal ultrasound, a contrast CT of the abdomen is recommended after intact removal of a stone in an asymptomatic patient to ensure that there is no residual obstruction. If a patient has either of these findings on imaging, or remains symptomatic despite negative studies, continued observation/imaging or secondary intervention is left to the discretion of the practitioner. Ultrasound imaging is sufficient for patients with radiopaque stones if they are asymptomatic. However, if hydronephrosis is evident or if the patient is symptomatic, low dose NCCT of the abdomen and pelvis is advised to identify obstructing fragments or stricture, and further intervention is left to the discretion of the practitioner. Patients with persistent symptoms despite negative imaging can undergo continued observation or further imaging as indicated.

SUMMARY

When considering imaging for the management of ureteral calculi one must weigh the desire for diagnostic accuracy against the potential risks of radiation exposure and cost. Adhering to the principle of ALARA and understanding the recommendations set forth in the AUA clinical effectiveness protocol should provide a framework upon which decisions about imaging are made.

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1. A 35-year-old man underwent uncomplicated ureteroscopy for a 6 mm radiopaque right distal ureteral calculus and the stone was removed intact. The follow-up office visit should include
   a. no imaging
   b. renal ultrasound
   c. KUB
   d. KUB and renal ultrasound

2. A 42-year-old man with BMI <30 underwent SWL for a 9 mm left proximal ureteral calculus. He passed a few fragments and is asymptomatic. At 3-week follow-up renal ultrasound shows no hydronephrosis but KUB reveals a small column of fragments in the mid ureter. The next step is
   a. medical expulsive therapy and re-image with KUB and ultrasound in a few weeks
   b. non-contrast low dose CT of the abdomen and pelvis
   c. ureteroscopy and laser lithotripsy
   d. placement of percutaneous nephrostomy tube

3. A patient with a BMI of 32 was treated with medical expulsive therapy for an 8 mm left mid ureteral stone. Despite passing the stone (which he has in hand) last week, he continues to complain of left flank pain. Renal ultrasound reveals mild left hydronephrosis. The next step is
   a. no further imaging is needed if the passed stone is 8 mm
   b. low dose protocol non-contrast CT of the abdomen and pelvis
   c. KUB
   d. standard protocol non-contrast CT of the abdomen and pelvis

4. A 42-year-old man is seen in the emergency department with right flank pain. Non-contrast CT of the abdomen and pelvis reveals a 6 mm right distal ureteral stone not visible on CT scout. He is afebrile and the pain is well controlled. The next step is
   a. obtain KUB
   b. proceed with SWL
   c. discharge on medical expulsive therapy and pain medication
   d. discharge on potassium citrate and pain medication

5. A 25-year-old healthy woman at 26 weeks of gestation is seen in the emergency department with fever and right flank pain. Renal and abdominal ultrasound shows bilateral hydronephrosis (right>left) with no obvious stone seen in the kidneys or visualized ureters. Ureteral jets were not appreciated on either side after 10 minutes of observation. What is the next step?
   a. Limited IVP
   b. KUB with tomograms
   c. Low dose CT of the abdomen and pelvis
   d. Placement of right percutaneous nephrostomy tube

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