American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Acute Onset Flank Pain — Suspicion of Stone Disease**

Variant 1: **Suspicion of stone disease.**

Radiologic Procedure	Rating	Comments	RRL*
CT abdomen and pelvis without contrast	8	Reduced-dose techniques preferred.	☢☢☢☢
CT abdomen and pelvis without and with contrast	6	If CT without contrast does not explain pain or if without has abnormality that should be further assessed with contrast (ex. stone versus phleboliths).	☢☢☢☢
US kidneys and bladder retroperitoneal with Doppler and KUB	6	Preferred examination in pregnancy, in patients who are allergic to iodinated contrast, and if NCCT is not available.	☢☢
X-ray intravenous urography	4		☢☢☢
MRI abdomen and pelvis without contrast (MR urography)	4		O
MRI abdomen and pelvis without and with contrast (MR urography)	4	See statement regarding contrast in text under "Anticipated Exceptions."	O
CT abdomen and pelvis with contrast	2		☢☢☢☢
X-ray abdomen and pelvis (KUB)	1	Most useful in patients with known stone disease.	☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Variant 2: **Recurrent symptoms of stone disease.**

Radiologic Procedure	Rating	Comments	RRL*
CT abdomen and pelvis without contrast	7	Reduced-dose techniques preferred.	☢☢☢☢
US kidneys and bladder retroperitoneal with Doppler and KUB	7		☢☢
CT abdomen and pelvis without and with contrast	6	If CT without contrast does not explain pain or if without has abnormality that should be further assessed with contrast (eg, stone versus phleboliths).	☢☢☢☢
X-ray abdomen and pelvis (KUB)	6	Good for baseline and post-treatment follow-up.	☢☢
MRI abdomen and pelvis without contrast (MR urography)	4		O
MRI abdomen and pelvis without and with contrast (MR urography)	4	See statement regarding contrast in text under "Anticipated Exceptions."	O
CT abdomen and pelvis with contrast	2		☢☢☢☢
X-ray intravenous urography	2		☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

ACUTE ONSET FLANK PAIN — SUSPICION OF STONE DISEASE

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Summary of Literature Review

Urinary tract stones (calculi) are thought to result from either excessive excretion or precipitation of salts in the urine or a relative lack of inhibiting substances. Men are more commonly affected than women, and the incidence increases with age until age 60. Blacks and children are affected less frequently. Renal calculi tend to be recurrent, and flank pain is a nonspecific symptom that may be associated with other entities; therefore, evaluation with imaging is recommended at the initial presentation [1].

A renal calculus small enough to pass into the ureter may cause blockage of urine flow with distension of the upper urinary tract. Ureteral hyperperistalsis occurs, resulting in acute onset of sharp, spasmodic flank pain and hematuria. The ureter contains several areas where calculi commonly become lodged (eg, at the ureteropelvic junction, the iliac vessels, and the ureterovesical junction). The probability of spontaneous passage of a ureteral calculus measuring ≤5 mm in axial diameter is very high. A meta-analysis of five patient groups (224 patients) yielded an estimate that 68% of such stones would pass spontaneously (95% confidence interval [CI], 46%-85%) [2]. A 10 mm calculus, however, is very unlikely to pass spontaneously. Therefore, the treating physician wants to know the size of the calculus as well as its location and its effect on renal function.

Patients with a suspected diagnosis of renal colic have traditionally been evaluated with urinalysis, abdominal radiography of the kidney, ureter, and bladder, commonly referred to as the KUB procedure, or excretory urography, commonly referred to as intravenous urography (IVU). More recently, ultrasonography (US), computerized tomography (CT), and magnetic resonance imaging (MRI) have been used.

Radiography

Radiography of the abdomen may be sufficient to diagnose ureterolithiasis in patients with known stone disease and previous KUBs. The sensitivity of the KUB for ureterolithiasis in other patients is poor. Studies by Roth et al [3] and Mutgi et al [4] found sensitivities of 62% and 58% when the radiographs were interpreted retrospectively. Levine et al [5] correlated the KUB with noncontrast CT (NCCT) retrospectively, so that an exact correlation was made between stones on the CT scan and the calcific density on the KUB. A sensitivity of only 59% was found for detecting ureteral calculi on the KUB. Ripolles et al [6] used the KUB as a guide for US evaluation of flank pain. They found 64% sensitivity for detecting ureteral calculi and had six false positive cases among the 66 patients evaluated. While the KUB may be a valuable part of the IVU or US evaluation of flank pain, it has a very limited role when used alone, and it should not be used to triage which patients should receive NCCT. Mermuys et al [7] found digital tomosynthesis to be more sensitive than digital radiography for diagnosing renal stones. However, overall sensitivity for digital tomosynthesis was 59% for renal stones and 29% for ureteral stones, with noncontrast CT used as the gold standard [7].

Computed Tomography

Since the introduction of the use of helical (spiral) NCCT as the initial study in evaluating flank pain by Smith et al [8], numerous investigations have confirmed it to be the study with the highest sensitivity (95%-96%) and

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specificity (98%) for ureterolithiasis [9-14]. Virtually all stones are radio-opaque, and stone size can be measured accurately in cross-section, aiding in predicting outcome. Stone location, accurately depicted by NCCT, has also been associated with spontaneous stone passage rates, with the more proximal stones having a higher need for intervention [15]. Recently, coronal reformations of axial CT scans have been shown to more accurately predict stone size in the craniocaudad direction, although this dimension is not critical to estimating the likelihood of stone passage [16]. Review of coronal reformations has also been shown in two studies to increase the rate of detection of stones when reviewed with the axial dataset [17,18], but was found to be equivalent to the axial dataset in one study [17,19]. Estimation of maximal stone size was also improved by using coronal reformations [18]. The degree of perinephric stranding present on the affected side on NCCT has also been shown to correlate inversely with the likelihood of stone passage, giving additional prognostic information [10], but this finding has been disputed in other studies [20,21].

The amount of stranding is related to the time after onset of pain and is usually not seen in the first 2 hours following the onset of flank pain. It may take up to 8 hours after the onset of pain to become maximal [22]. Secondary signs such as ureteral dilatation and perinephric stranding allow CT to make a diagnosis of a recently passed stone [11,12]. NCCT has been directly compared with IVU in four series [8,14,23,24]. NCCT was equal to IVU in diagnosing obstruction and more reliable in diagnosing the presence of nephrolithiasis. NCCT is also reliable for diagnosing flank pain due to causes other than ureterolithiasis [13,23-25], such as appendicitis and diverticulitis. NCCT is safer than IVU since it uses no contrast media, is rapid (with the entire study taking minutes), and does not require the technical expertise that US does. When CT is available, it is the best first study in the nonpregnant adult presenting with flank pain likely to be due to stone disease, and it has been shown to be more cost-effective than IVU [24,26]. If there is uncertainly about whether a calcific density represents a ureteral calculus or a phlebolith at noncontrast CT, intravenous contrast material can be administered and excretory phase images obtained for definitive diagnosis [27,28].

Concerns over radiation exposure, especially in young stone patients, have led to the development and evaluation of reduced-dose regimens [29-35]. NCCT using an ultra-low-dose protocol could also be considered, as was reported by White et al [36]. In this retrospective review of 20 pregnant patients (average gestational age: 26.5 weeks) with suspected renal colic, low-dose NCCT (mean mAs, 109) confirmed stones in 13, severe hydronephrosis in two, and no significant findings in five. Jin et al [37] reported similar detection of renal stones at 30 mAs as compared to 100 mAs in cadaver kidneys. Low-dose techniques using automated tube current modulation have also been found to be accurate for detecting renal and ureteral calculi. Ciaschini et al found that there was no difference in the detection of calculi >3 mm when reconstructions of raw CT data were performed at 100%, 50%, and 25% of the original dose using simulation software [38]. Mulkens et al [35] also found similar sensitivity, specificity, and accuracy of stone detection for routine dose CT compared with low-dose CT using automated tube current modulation. A meta-analysis of seven studies assessing the diagnostic performance of low dose (<3 mSv) CT for detecting urolithiasis found a pooled sensitivity of 97% and a pooled specificity of 95% [39].

Other recent technique refinement has included evaluation of the effect of slice width and overlapping image reconstruction on stone detection [40]. Limiting scan range to include only the kidneys, ureters, and bladder and using a low kVp technique have also been advocated as ways to reduce dose [41].

Dual-energy techniques can be applied to try to characterize renal calculi composition at CT. Using these techniques and subtracting attenuation values at 80 kV from attenuation values at 120 kV, Grosjean et al [42] were able to differentiate uric acid, cystine, struvite, weddellite, brushite, and whewellite stones in a phantom study. However, performance deteriorated when motion was simulated [42]. Boll et al [43] were also able to characterize renal calculi in vitro using dual-energy CT techniques by evaluating the ratio of a stone's attenuation at 140 kVp and at 80 kVp.

Intravenous Urography

The IVU is the previous standard study for ureterolithiasis and is still the best investigation if NCCT is not available. It provides information regarding site and degree of obstruction, size of stone, and effect of obstruction on renal excretion. Nephrotomography may be useful to help distinguish renal calculi from intestinal contents. This examination has a number of relative contraindications, including renal insufficiency, dehydration, past reaction to iodinated contrast agents, and pregnancy. The availability of nonionic iodinated contrast material has reduced the risk of reaction. It may take several hours for excretion to occur in the presence of acute obstruction, in which case IVU is more time-consuming than the alternative techniques. Another disadvantage of IVU is its inability to identify alternative diagnoses.

Ultrasound

US is a safe, noninvasive imaging modality that can be used to study the urinary tract effectively. The diagnosis of obstructive urinary tract calculi depends on identification of the offending calculus and concomitant pelvicaliectasis and ureterectasis extending to the obstructing site [44,45]. Because it may take many hours for pelvicaliectasis and ureterectasis to develop, US reportedly will miss over 30% of acute obstructions caused by a uretheral stone in patients who are not specifically hydrated for the study. Laing et al [46] and Svedstrom et al [47] detected hydronephrosis in seven of 20 nonhydrated patients (35%) and 16 of 22 nonhydrated patients (73%), respectively, with ureteral calculi. More recently, US has been found to be 100% sensitive for signs of obstruction (hydronephrosis, ureteral dilatation, and/or perirenal fluid), perhaps indicating improvement in US equipment [6]. The use of intrarenal Doppler US improves the detection of early obstruction by evaluating for elevated resistive index (RI) in kidneys with nondilated collecting systems [48,49]. However, the sensitivity of US as compared to noncontrast CT for detecting renal calculi is quite low, ranging from 24%-57% and is especially poor for small stones [50,51].

Since KUB is superior to US in detecting ureteral calculi, Dalla Palma et al have recommended a combination of KUB and US. US in these cases is used to detect ureteropyelocaliectasis and then to trace the dilated ureter to a shadowing stone. US can also evaluate the presence and type of ureteral jet (with obstruction the jets are absent, diminished significantly in frequency, or a constant slow trickle). In a series of 180 patients, the authors showed a 95% negative predictive value of the KUB/US combination, indicating that IVU is not likely to be helpful if the KUB/US tests are negative. However, IVU is indicated if the KUB/US combination is equivocal or if interventional treatment is anticipated [52].

Svedstrom et al [47] also performed a comparison of KUB, US, a combination of KUB/US, and IVU in 49 patients. The accuracies of KUB (61%) and US (69%) were lower than that of IVU (92%). The accuracy of the combination of KUB/US was 71%, still lower than that of IVU. In an effort to reduce the number of IVU examinations needed, a model was tested in which only patients with negative US results went on to have an IVU. This algorithm showed 93% sensitivity and 79% specificity. The KUB/US combination has also been compared to NCCT [6]. In a prospective study of 66 patients, the KUB/US combination had a sensitivity of 79% (vs 93% for NCCT) for detecting ureteral stones. All missed cases had spontaneous stone passage, leading the authors to conclude that after a negative KUB/US combination, NCCT would not add useful information. The authors suggest use of NCCT in patients who fail to respond to conservative management or in those in whom surgery is anticipated. The advantage of US is its lack of ionizing radiation and its ability to show some calculi. For this reason it has been suggested for evaluating stones in pregnant women [53]. Its disadvantages include the need for skilled personnel, its inability to accurately measure the size of the calculus, the need to observe the ureteral jet phenomenon at the ureterovesical junction, and its inability to differentiate dilatation without obstruction from true obstruction [54,55].

Magnetic Resonance Imaging

Regan et al [56] applied magnetic resonance urography (MRU) to the evaluation of 23 patients with acutely obstructed kidneys. They found 100% sensitivity for diagnosing obstruction, with perirenal fluid seen in 21 of 23 obstructed kidneys (87%) and in no normal kidneys. The site of the obstruction was seen in 80% of these obstructed kidneys. Round signal voids corresponding to the location of stones on correlative IVUs were seen in 12 of 18 patients with ureteric obstruction caused by a stone. These appearances were nonspecific and were also seen secondary to blood clot or tumor. Zielonko et al [57] examined 60 patients with obstructive uropathy. In the 13 patients with ureteric stones, MRU correctly identified the site of obstruction in 12 (one stone moved between the MRU and confirmatory imaging). Forty-six percent of the stones were seen as signal voids against a background of bright urine on T2-weighted images. MRU has been successfully used in pregnant patients with flank pain [58]. Thoeny et al [59] found increased oxygen content in the renal cortex and medulla with acute unilateral renal obstruction using blood oxygen level-dependent (BOLD) MRI. Diffusion weighted imaging has also been shown to detect changes in renal perfusion and diffusion in the setting of acute ureteral obstruction [60]. Sudah et al found higher sensitivity for detecting ureteral stones with excretory MRU as compared to T2W MRU, although the former technique is not recommended for pregnant patients [61].

Imaging of the Pregnant Patient with Suspicion of Stone Disease

Ureteral calculi can be a source of abdominal pain in pregnant patients. US frequently is used as a screening examination, as US is a sensitive and specific test for diagnosing hydronephrosis [62]. However, the differential diagnosis of hydronephrosis in the pregnant patient is confounded by physiologic hydronephrosis of pregnancy, which is thought to be caused by compression of the ureters between the gravid uterus and the linea terminalis [63]. Physiologic hydronephrosis of pregnancy occurs in greater than 80% of pregnant women, more commonly occurs on the right rather than the left, and is generally seen beginning in the second trimester [63]. Limited IVU (example: scout radiograph, film at 30 seconds and film at 20 minutes) has also been used to diagnose ureteral obstruction in pregnant patients [64].

Low-dose noncontrast CT has been shown to be a sensitive and specific test for diagnosing ureteral calculi in pregnant patients [36]. With a goal of not irradiating an intrauterine pregnancy, MRU has also been advocated for the detection of ureteral calculi at some centers [65]. However, in a study by Shokeir et al [66] in nonpregnant patients, the site of stone impaction was identified by noncontrast CT in 146 of 146 renal units (100% sensitivity) and by MRU in only 101 of 146 renal units (69% sensitivity). A recent survey of academic medical centers found that radiologists are more likely to image for suspected renal calculus with CT rather than with MR in the second (35% vs 20%) and third (48% vs 18%) trimesters [67].

Recurrent Symptoms of Stone Disease

In addition to pregnant patients, the patient with known stone disease and recurrent symptoms also presents a challenge. In this setting, the likelihood of stone disease as the cause of flank pain is higher [9], but repeated NCCTs raise a concern about excessive radiation exposure. Katz et al [68] examined the issue of radiation exposure associated with repetitive NCCT in this setting. In a 6-year period, 5,564 NCCTs were performed for renal colic. While the vast majority of patients (96%) underwent one or two NCCTs with an estimated effective dose of 6.5-17 mSv, 176 patients had three or more NCCTs with an estimated dose of 20-154 mSv. One patient had 18 NCCTs over the 6 years.

An additional study of this problem was recently published in the emergency medicine literature by Broder et al [69]. In this retrospective study of 356 patient encounters representing 306 individuals seen in the emergency department over a period of 10 months for suspected renal colic, 262 encounters included NCCT. While 49 of the patients did not undergo CT scanning, 14 had one NCCT, 151 (49%) had two NCCTs and 92 had three or more NCCTs in the emergency department. This final group included a 28-year-old woman with 14 scans, a 42-year-old woman with 22 scans, and a 53-year-old man with 25 scans. In this setting, every effort should be made to use low-dose NCCT. A recent study by Poletti et al found excellent sensitivity (95%) and specificity (97%) for detecting stones with a low-dose protocol (30 mAs) compared to a standard-dose protocol (180 mAs) in patients with a body mass index (BMI) of <30 [34].

In another recent study, Mulkens et al [35] studied 300 patients, half of whom underwent standard-dose NCCT (95-120 mAs) and half of whom underwent low-dose NCCT (51-70 mAs), and found high sensitivity (97.3%-98.6%) and specificity (93.5%) for detecting urinary tract stones in the low-dose group (comparable to the high-dose group). These excellent results may in part be due to the use of dose modulation. In the subset of obese or overweight patients, sensitivity and specificity were also high (97%-100%), leading them to conclude that low-dose NCCT is a viable examination even in larger patients. Further, if the patient has persistence of symptoms from a documented stone and repeat imaging is contemplated, a limited NCCT of the area of the stone through the bladder could be considered if stone passage is the main question. Alternatively, if the stone can be seen by KUB, a repeat KUB might provide useful information at a much lower dose.

Summary

- NCCT is the most rapid and accurate technique for evaluating flank pain.
- If there is uncertainly about whether a calcific density represents a ureteral calculus or a phlebolith, intravenous contrast material can be administered and excretory phase images obtained for definitive diagnosis.
- IVU, which is readily available and is familiar to nonradiologic physicians, is the technique of choice if CT is not available.
- In pregnant patients with flank pain, US is the best initial study.

- While a limited IVU has been used to evaluate flank pain in pregnancy when the US study is not diagnostic, MRU has potential utility in diagnosing acute urinary tract obstruction without the use of ionizing radiation.
- NCCT using an ultra-low-dose protocol could also be considered in pregnant patients in the second and third trimester.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (ie, <30 mL/min/1.73m^2), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73m^2. For more information, please see the ACR *Manual on Contrast Media* [70].

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies".

Supporting Documents

- ACR Appropriateness Criteria® Overview
- Procedure Information
- Evidence Table

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