

**American College of Radiology  
ACR Appropriateness Criteria®**

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

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

Radiologic Procedure	Rating	Comments	RRL*
CT abdomen and pelvis without IV contrast	8	Reduced-dose techniques are preferred.	☼☼☼☼
CT abdomen and pelvis without and with IV contrast	6	This procedure is indicated if CT without contrast does not explain pain or reveals an abnormality that should be further assessed with contrast (eg, stone versus phleboliths).	☼☼☼☼
US color Doppler kidneys and bladder retroperitoneal	6		O
X-ray intravenous urography	4		☼☼☼
MRI abdomen and pelvis without IV contrast	4	MR urography.	O
MRI abdomen and pelvis without and with IV contrast	4	MR urography.	O
X-ray abdomen and pelvis (KUB)	3	This procedure can be performed with US as an alternative to NCCT.	☼☼
CT abdomen and pelvis with IV contrast	2		☼☼☼☼
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

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

Radiologic Procedure	Rating	Comments	RRL*
CT abdomen and pelvis without IV contrast	7	Reduced-dose techniques are preferred.	☼☼☼☼
US color Doppler kidneys and bladder retroperitoneal	7	This procedure is indicated in an emergent setting for acute management to evaluate for hydronephrosis. For planning and intervention, US is generally not adequate and CT is complementary as CT more accurately characterizes stone size and location.	O
CT abdomen and pelvis without and with IV contrast	6	This procedure is indicated if CT without contrast does not explain pain or reveals an abnormality that should be further assessed with contrast (eg, stone versus phleboliths).	☼☼☼☼
X-ray abdomen and pelvis (KUB)	5	This procedure can be performed with US as an alternative to NCCT.	☼☼
MRI abdomen and pelvis without IV contrast	4	MR urography.	O
MRI abdomen and pelvis without and with IV contrast	4	MR urography.	O
CT abdomen and pelvis with IV contrast	2		☼☼☼☼
X-ray intravenous urography	2		☼☼☼
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

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

**Variant 3:** Pregnant patient.

Radiologic Procedure	Rating	Comments	RRL*
US color Doppler kidneys and bladder retroperitoneal	8		O
CT abdomen and pelvis without IV contrast	6		⊗⊗⊗⊗
MRI abdomen and pelvis without IV contrast	5		O
CT abdomen and pelvis without and with IV contrast	2		⊗⊗⊗⊗
CT abdomen and pelvis with IV contrast	2		⊗⊗⊗⊗
X-ray abdomen and pelvis (KUB)	2		⊗⊗
X-ray intravenous urography	1		⊗⊗⊗
MRI abdomen and pelvis without and with IV contrast	1		O
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

## ACUTE ONSET FLANK PAIN—SUSPICION OF STONE DISEASE (UROLITHIASIS)

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### **Summary of Literature Review**

#### **Introduction/Background**

Urinary tract stones 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 years. Children are affected less frequently. Stones 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 stone 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. Irritation of and trauma to the ureter may also result in hematuria. The ureter contains several areas where stones commonly become lodged (eg, at the ureteropelvic junction, the iliac vessels, and the ureterovesical junction). The probability of spontaneous passage of a stone is size dependent, and the probability is inversely proportional to stone size. A meta-analysis yielded an estimate that a calculus  $\leq 5$  mm has a 68% probability of spontaneous passage [2]. A 10-mm stone, however, is very unlikely to pass spontaneously. Therefore, the treating physician wants to know the size of the stone as well as its location.

#### **Overview of Imaging Modalities**

Presently, noncontrast computed tomography (NCCT) is commonly performed in the evaluation of patients with suspected renal colic [3]. NCCT is highly accurate for the identification of stones, for detecting evidence of ureteral obstruction, and for the identification of other potential etiologies of flank pain. The major disadvantage of NCCT is radiation exposure to the patient. In patients with known urolithiasis and/or a presentation classic for renal colic, the combination of abdomen and pelvis radiography (KUB) and ultrasound (US) may be an acceptable and lower-radiation alternative for the diagnosis of clinically significant stones. Magnetic resonance imaging (MRI) is an excellent tool for the evaluation of hydronephrosis though is limited in its ability to detect small stones.

#### **Discussion of Imaging Modalities by Variant**

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

##### *Computed Tomography*

Since the introduction of the use of helical (spiral) NCCT as the initial study in evaluating flank pain by Smith et al [4], numerous investigations have confirmed it to be the study with the highest (>95%) sensitivity and specificity for urolithiasis. Virtually all stones are radiopaque on CT, 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 [5]. Review of coronal reformations has also been shown in 2 studies to increase the rate of detection of stones when reviewed with the axial dataset [6,7] but was found to be equivalent to the axial dataset in 1 study

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[6,8]. Estimation of maximal stone size was also improved by using coronal reformations [7,9]. Accuracy of stone measurement is improved with bone windows and magnified views [10]. Because urologic management is based on maximal stone diameter [2], stone measurements should be provided in the coronal and axial plane.

Concerns over radiation exposure, especially in young stone patients, have led to the development and evaluation of reduced-dose CT regimens [11-20]. If CT is being performed to evaluate for renal or ureteral stones, a low-dose protocol should be performed [21]. Techniques for lowering dose include using a lower kVp, lower tube current, use of automated tube current modulation, and use of iterative reconstruction [13]. Limiting scan range to include only the kidneys, ureters, and bladder also reduces dose [22]. In a recent study of adults, the mean radiation dose was found to be 1.9 mGy with a low-dose protocol as compared to 9.9 mGy for a conventional protocol with similar diagnostic accuracy [13]. Tube currents as low as 40 mA are acceptable for stone detection in pediatric patients weighing  $\leq 50$  kg [23].

A meta-analysis of 7 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% [24]. Sensitivity for stone detection decreases with smaller stone size. Sensitivity for small stones can be further hampered with increasing dose reduction [25]. However, using moderate dose reduction (50%) with iterative reconstruction is not inferior to full-dose scans reconstructed with filtered back projection in stone detection [26]. Low-dose CT has also been shown to yield equivalent stone measurements as compared to standard-dose CT [27].

If there is uncertainty about whether a calcific density represents a stone or a phlebolith at NCCT, intravenous contrast material can be administered and excretory phase images obtained for definitive diagnosis [28,29]. Secondary signs such as ureteral dilatation and perinephric stranding allow CT to make a diagnosis of a recently passed stone [30,31]. NCCT is also reliable for diagnosing flank pain due to causes other than ureterolithiasis [32-35], such as appendicitis and diverticulitis. CT abdomen and pelvis performed with intravenous contrast material is 81% sensitive for detection of all renal stones and  $> 95\%$  sensitive for detection of stones  $\geq 3$  mm [36].

Dual-energy CT has been shown to be a useful tool for the characterization of stone composition, though the best energy levels for imaging and postprocessing algorithm remain to be determined [37-42]. Preliminary investigations also indicate that virtual unenhanced images obtained using dual-energy techniques are reasonably accurate in subtracting excreted contrast material from renal collecting systems and can be used to diagnose stones  $> 2.9$  mm with good reliability [43]. However, virtual unenhanced images created using dual-energy techniques are thought to not be accurate enough to currently replace true unenhanced images [44].

### *Radiography*

Radiography may suggest the etiology for renal colic if a calcification is visible in the expected location of the ureter on the side of the patient's pain. However, not all stones are visible at radiography. Additionally, some calcifications visible at radiography may not be in the ureter but may be phleboliths or other vascular calcifications. Also, the sensitivity of the KUB for ureterolithiasis varies depending on a number of factors, including stone composition, location, and size, as well as patient body habitus and overlying bowel contents. When compared to NCCT as the reference standard, Jung et al [45] found digital radiography to be 72% sensitive for large ( $> 5$  mm) stones in the proximal ureter but only 29% sensitive overall for the detection of stones of any size in any location. Levine et al [46] also correlated KUB findings with NCCT findings retrospectively and found a sensitivity of 59% for detecting stones on KUB.

Radiography exposes the patient to less radiation as compared to CT. The effective radiation dose from a single abdominal radiograph is approximately 0.8 mSv as compared to 10–12 mSv for conventional NCCT of the abdomen and pelvis and 3–4 mSv for low-dose NCCT of the abdomen and pelvis. However, multiple radiographs can reach an exposure range similar to a low-dose CT. For example, a KUB with bilateral oblique views results in an effective radiation dose of approximately 2.4–2.7 mSv.

### *Ultrasound*

US can be a useful tool in the evaluation of patients with suspected renal colic and does not expose the patient to ionizing radiation. US may be able to visualize a stone as well as demonstrate findings of obstructive uropathy.

In the setting of acute flank pain and with meticulous technique, US has been shown to be 61%–90% sensitive for the detection of stones [47,48]. Using color Doppler imaging to assess for the twinkle artifact [49,50] may improve the ability to detect stones [47]. The twinkle artifact is visible as an intense multicolored signal behind a

stone with the use of color Doppler technique [47]. However, the sensitivity of US as compared to NCCT for detecting stones overall can be quite low, ranging from 24%–57%, and is especially poor for small stones [51,52].

US has been found to be up to 100% sensitive and 90% specific for the diagnosis of ureteral obstruction in patients presenting with acute flank pain [53]. US findings of obstructive uropathy include hydronephrosis, ureterectasis, and perinephric fluid [53]. However, within the first 2 hours of presentation, these findings are less sensitive because, for example, hydronephrosis may not have had time to develop [54].

Outcomes were similar but radiation exposure was lower when individuals with suspected nephrolithiasis who presented to the emergency department were evaluated initially with US as compared to CT in a recent randomized study of 2759 individuals [55]. In this large study, there were no statistically significant differences in return emergency department visits, hospitalizations, or high-risk diagnoses with complications for individuals whose initial imaging workup began with US (performed as point-of-care imaging in the emergency department or performed in the radiology department) as compared to individuals whose initial imaging workup began with CT [55]. Of note, 27%–41% of patients who initially underwent US then underwent a subsequent CT during the initial emergency department visit, and men weighing >285 lb, women weighing >250 lb, and individuals undergoing hemodialysis were excluded from the study [55]. Additionally, US and CT were considered true positives only if a stone was removed or passed as reported by the patient, and this reference standard likely underestimates the presence of urinary stone burden [55].

A combination of an abdominal radiograph and US can be considered as a lower-radiation and less expensive alternative to NCCT for the evaluation of individuals with suspected renal colic. Though the combined use of these modalities is not as sensitive for stones (especially small stones) as compared to NCCT, a number of authors have come to the conclusion that these 2 modalities are accurate enough in the detection of clinically significant stones that KUB/US should be an acceptable alternative to NCCT for some patients [53,56]. In a prospective study of 66 patients, the KUB/US combination had a sensitivity of 79% (versus 93% for NCCT) for detecting stones [53]. 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 [53]. The authors suggest the use of NCCT in patients who fail to respond to conservative management or in those for whom surgery is anticipated.

Advantages of US are its lack of ionizing radiation and its ability to demonstrate some stones. Its disadvantages include the need for skilled personnel, its inability to accurately measure the size of the stone, the need to observe the ureteral jet phenomenon at the ureterovesical junction, and its inability to differentiate dilatation without obstruction from true obstruction [57,58].

### *Magnetic Resonance Imaging*

MRI can be considered as an alternative to low-dose NCCT in certain patient populations, such as pregnant women (noncontrast MRI), young individuals, and individuals who have undergone multiple prior CT examinations [59]. In general, MRI is highly accurate for the diagnosis of hydronephrosis and perinephric edema but is less accurate in directly visualizing stones as compared to NCCT [60].

Regan et al [61] 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 locations of stones on correlative intravenous urogram (IVU) were seen in 12 of 18 patients with ureteric obstruction caused by a stone. Zielonko et al [62] examined 60 patients with obstructive uropathy. In the 13 patients with stones, MRU correctly identified the site of obstruction in 12 (1 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. A more recent study found that MR-visible stones measured an average of 1.1 cm (range, 0.15–3.3 cm), and stones not visible at MR measured an average of 0.46 cm (range, 0.1–0.9 cm) [63]. Thoeny et al [64] found increased oxygen content in the renal cortex and medulla with acute unilateral renal obstruction using blood oxygen level–dependent MRI. Diffusion-weighted imaging has also been shown to detect changes in renal perfusion and diffusion in the setting of acute ureteral obstruction [65]. Sudah et al [66] found a higher sensitivity for detecting stones with excretory MRU as compared to T2-weighted MRU, although the former technique is not recommended for pregnant patients.

### *Intravenous Urography*

The IVU is the previous standard study for ureterolithiasis. It provides information regarding site and degree of obstruction, stone size, and effect of obstruction on renal excretion. Nephrotomography may be useful to help distinguish renal calculi from intestinal contents. IVU 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.

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

The patient with known urolithiasis and recurrent symptoms also presents a challenge. In this setting, the likelihood of urolithiasis as the cause of flank pain is higher [67], but repeated NCCTs raise a concern about excessive radiation exposure. Katz et al [68] examined the issue of radiation exposure associated with repetitive NCCTs in this setting. In a 6-year period, 5564 NCCTs were performed for renal colic. Although the vast majority of patients (96%) underwent 1 or 2 NCCTs, with an estimated effective dose of 6.5–17 mSv, 176 patients had 3 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 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. Although 49 of the patients did not undergo CT scanning, 14 had 1 NCCT, 151 (49%) had 2 NCCTs, and 92 had 3 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 a low-dose technique if NCCT is required.

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. KUBs can be used to follow stones that are visible on the scout radiograph of a CT [70]. Stones that are not visible on the CT scout radiograph may not be visible on a follow-up KUB [70]. However, larger stones (>9.7 mm) may be visible on follow-up KUBs in thin patients, depending on stone composition, even if the stone is not visible on the CT scout radiograph [70].

If an individual with known urolithiasis presents with recurrent symptoms of stone disease, US is a relatively inexpensive and radiation-free option to evaluate for hydronephrosis indicating ureteral obstruction. Additionally, individuals with known renal stones may have prior imaging demonstrating the number and location of their renal stones. KUB can then be used to assess overall stone burden and to evaluate for stones that have moved, though depending on their size and composition, some stones may be difficult to identify on KUBs.

#### **Variant 3: Pregnant patient.**

Stones can be a source of abdominal pain in pregnant patients. US is frequently used as a screening examination, as US is a sensitive and specific test for diagnosing hydronephrosis and does not expose the patient or fetus to ionizing radiation [71-73]. 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 [74]. Physiologic hydronephrosis of pregnancy occurs in >80% of pregnant women, more commonly occurs on the right than the left, and is generally seen beginning in the second trimester [74].

Low-dose NCCT has been shown to be a sensitive and specific test for diagnosing stones in pregnant patients [75]. With a goal of avoiding irradiation of the fetus, MRU has also been advocated for the detection of ureteral calculi at some centers [76]. However, in a study by Shokeir et al [77] in nonpregnant patients, the site of stone impaction was identified by NCCT 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 than with MR in the second (35% versus 20%) and third (48% versus 18%) trimesters [78].

## Summary of Recommendations

- NCCT is the most accurate technique for evaluating flank pain.
- Low-dose NCCT should be performed when evaluating for renal or ureteral stones.
- If there is uncertainty about whether a calcific density represents a ureteral stone or a phlebolith, intravenous contrast material can be administered and excretory-phase images obtained for definitive diagnosis.
- In pregnant patients with flank pain, US is the best initial study.
- Abdominal radiography combined with US may be able to diagnose most clinically significant stones and should be considered, especially in young patients and those with known stone disease.
- MR could be considered to evaluate for hydronephrosis though is less accurate for the direct visualization of renal and ureteral stones.

## Summary of Evidence

Of the 82 references cited in the *ACR Appropriateness Criteria® Acute Onset Flank Pain-Suspicion of Stone Disease (Urolithiasis)* document, 81 of them are categorized as diagnostic references including 5 well designed studies 23 good quality studies, and 23 quality studies that may have design limitations. There are 30 references that may not be useful as primary evidence. There is 1 reference that is a meta-analysis study.

The 82 references cited in the *ACR Appropriateness Criteria® Acute Onset Flank Pain-Suspicion of Stone Disease (Urolithiasis)* document were published from 1982-2014.

While there are references that report on studies with design limitations, 28 well designed or good quality studies provide good evidence.

## Safety Considerations in Pregnant Patients

Imaging of the pregnant patient can be challenging, particularly with respect to minimizing radiation exposure and risk. For further information and guidance, see the following ACR documents:

- [ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation](#) [79]
- [ACR-ACOG-AIUM-SRU Practice Parameter for the Performance of Obstetrical Ultrasound](#) [80]
- [ACR Guidance Document on MR Safe Practices](#) [81]
- [ACR Manual on Contrast Media](#) [82]

## 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
○	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

For additional information on the Appropriateness Criteria methodology and other supporting documents go to [www.acr.org/ac](http://www.acr.org/ac).

### References

- Ha M, MacDonald RD. Impact of CT scan in patients with first episode of suspected nephrolithiasis. *J Emerg Med.* 2004;27(3):225-231.
- Preminger GM, Tiselius HG, Assimos DG, et al. 2007 guideline for the management of ureteral calculi. *J Urol.* 2007;178(6):2418-2434.
- Hyams ES, Korley FK, Pham JC, Matlaga BR. Trends in imaging use during the emergency department evaluation of flank pain. *J Urol.* 2011;186(6):2270-2274.
- Smith RC, Rosenfield AT, Choe KA, et al. Acute flank pain: comparison of non-contrast-enhanced CT and intravenous urography. *Radiology.* 1995;194(3):789-794.
- Coll DM, Varanelli MJ, Smith RC. Relationship of spontaneous passage of ureteral calculi to stone size and location as revealed by unenhanced helical CT. *AJR Am J Roentgenol.* 2002;178(1):101-103.
- Lin WC, Uppot RN, Li CS, Hahn PF, Sahani DV. Value of automated coronal reformations from 64-section multidetector row computerized tomography in the diagnosis of urinary stone disease. *J Urol.* 2007;178(3 Pt 1):907-911; discussion 911.
- Metser U, Ghai S, Ong YY, Lockwood G, Radomski SB. Assessment of urinary tract calculi with 64-MDCT: The axial versus coronal plane. *AJR Am J Roentgenol.* 2009;192(6):1509-1513.
- Memarsadeghi M, Schaefer-Prokop C, Prokop M, et al. Unenhanced MDCT in patients with suspected urinary stone disease: do coronal reformations improve diagnostic performance? *AJR Am J Roentgenol.* 2007;189(2):W60-64.
- Berkovitz N, Simanovsky N, Katz R, Salama S, Hiller N. Coronal reconstruction of unenhanced abdominal CT for correct ureteral stone size classification. *Eur Radiol.* 2010;20(5):1047-1051.
- Eisner BH, Kambadakone A, Monga M, et al. Computerized tomography magnified bone windows are superior to standard soft tissue windows for accurate measurement of stone size: an in vitro and clinical study. *J Urol.* 2009;181(4):1710-1715.
- Fracchia JA, Panagopoulos G, Katz RJ, Armenakas N, Sosa RE, DeCorato DR. Adequacy of low dose computed tomography in patients presenting with acute urinary colic. *J Endourol.* 2012;26(9):1242-1246.
- Jin DH, Lamberton GR, Broome DR, et al. Effect of reduced radiation CT protocols on the detection of renal calculi. *Radiology.* 2010;255(1):100-107.
- Kulkarni NM, Uppot RN, Eisner BH, Sahani DV. Radiation dose reduction at multidetector CT with adaptive statistical iterative reconstruction for evaluation of urolithiasis: how low can we go? *Radiology.* 2012;265(1):158-166.
- Heneghan JP, McGuire KA, Leder RA, DeLong DM, Yoshizumi T, Nelson RC. Helical CT for nephrolithiasis and ureterolithiasis: comparison of conventional and reduced radiation-dose techniques. *Radiology.* 2003;229(2):575-580.



15. Kalra MK, Maher MM, Toth TL, et al. Strategies for CT radiation dose optimization. *Radiology*. 2004;230(3):619-628.
16. Liu W, Esler SJ, Kenny BJ, Goh RH, Rainbow AJ, Stevenson GW. Low-dose nonenhanced helical CT of renal colic: assessment of ureteric stone detection and measurement of effective dose equivalent. *Radiology*. 2000;215(1):51-54.
17. Meagher T, Sukumar VP, Collingwood J, et al. Low dose computed tomography in suspected acute renal colic. *Clin Radiol*. 2001;56(11):873-876.
18. Mulkens TH, Daineffe S, De Wijngaert R, et al. Urinary stone disease: comparison of standard-dose and low-dose with 4D MDCT tube current modulation. *AJR Am J Roentgenol*. 2007;188(2):553-562.
19. Poletti PA, Platon A, Rutschmann OT, Schmidlin FR, Iselin CE, Becker CD. Low-dose versus standard-dose CT protocol in patients with clinically suspected renal colic. *AJR Am J Roentgenol*. 2007;188(4):927-933.
20. Tack D, Sourtzis S, Delpierre I, de Maertelaer V, Gevenois PA. Low-dose unenhanced multidetector CT of patients with suspected renal colic. *AJR Am J Roentgenol*. 2003;180(2):305-311.
21. Jain N, Robinson S. Towards evidence based emergency medicine: best BETs from the Manchester Royal Infirmary. BET 4: Investigating flank pain: can the CT stay low? *Emerg Med J*. 2012;29(8):687-688.
22. Kambadakone AR, Eisner BH, Catalano OA, Sahani DV. New and evolving concepts in the imaging and management of urolithiasis: urologists' perspective. *Radiographics*. 2010;30(3):603-623.
23. Karmazyn B, Frush DP, Applegate KE, Maxfield C, Cohen MD, Jones RP. CT with a computer-simulated dose reduction technique for detection of pediatric nephroureterolithiasis: comparison of standard and reduced radiation doses. *AJR Am J Roentgenol*. 2009;192(1):143-149.
24. Niemann T, Kollmann T, Bongartz G. Diagnostic performance of low-dose CT for the detection of urolithiasis: a meta-analysis. *AJR Am J Roentgenol*. 2008;191(2):396-401.
25. Ciaschini MW, Remer EM, Baker ME, Lieber M, Herts BR. Urinary calculi: radiation dose reduction of 50% and 75% at CT--effect on sensitivity. *Radiology*. 2009;251(1):105-111.
26. Remer EM, Herts BR, Primak A, et al. Detection of Urolithiasis: Comparison of 100% Tube Exposure Images Reconstructed with Filtered Back Projection and 50% Tube Exposure Images Reconstructed with Sinogram-affirmed Iterative Reconstruction. *Radiology*. 2014;272(3):749-756.
27. Sohn W, Clayman RV, Lee JY, Cohen A, Mucksavage P. Low-dose and standard computed tomography scans yield equivalent stone measurements. *Urology*. 2013;81(2):231-234.
28. Dalla Palma L, Pozzi-Mucelli R, Stacul F. Present-day imaging of patients with renal colic. *Eur Radiol*. 2001;11(1):4-17.
29. Kawashima A, Sandler CM, Boridy IC, Takahashi N, Benson GS, Goldman SM. Unenhanced helical CT of ureterolithiasis: value of the tissue rim sign. *AJR Am J Roentgenol*. 1997;168(4):997-1000.
30. Katz DS, Lane MJ, Sommer FG. Unenhanced helical CT of ureteral stones: incidence of associated urinary tract findings. *AJR Am J Roentgenol*. 1996;166(6):1319-1322.
31. Smith RC, Verga M, Dalrymple N, McCarthy S, Rosenfield AT. Acute ureteral obstruction: value of secondary signs of helical unenhanced CT. *AJR Am J Roentgenol*. 1996;167(5):1109-1113.
32. Eikefjord E, Askildsen JE, Rorvik J. Cost-effectiveness analysis (CEA) of intravenous urography (IVU) and unenhanced multidetector computed tomography (MDCT) for initial investigation of suspected acute ureterolithiasis. *Acta Radiol*. 2008;49(2):222-229.
33. Hoppe H, Studer R, Kessler TM, Vock P, Studer UE, Thoeny HC. Alternate or additional findings to stone disease on unenhanced computerized tomography for acute flank pain can impact management. *J Urol*. 2006;175(5):1725-1730; discussion 1730.
34. Smith RC, Verga M, McCarthy S, Rosenfield AT. Diagnosis of acute flank pain: value of unenhanced helical CT. *AJR Am J Roentgenol*. 1996;166(1):97-101.
35. Takahashi N, Kawashima A, Ernst RD, et al. Ureterolithiasis: can clinical outcome be predicted with unenhanced helical CT? *Radiology*. 1998;208(1):97-102.
36. Dym RJ, Duncan DR, Spektor M, Cohen HW, Scheinfeld MH. Renal stones on portal venous phase contrast-enhanced CT: does intravenous contrast interfere with detection? *Abdom Imaging*. 2014;39(3):526-532.
37. Eiber M, Holzappel K, Frimberger M, et al. Targeted dual-energy single-source CT for characterisation of urinary calculi: experimental and clinical experience. *Eur Radiol*. 2012;22(1):251-258.
38. Fung GS, Kawamoto S, Matlaga BR, et al. Differentiation of kidney stones using dual-energy CT with and without a tin filter. *AJR Am J Roentgenol*. 2012;198(6):1380-1386.

39. Kulkarni NM, Eisner BH, Pinho DF, Joshi MC, Kambadakone AR, Sahani DV. Determination of renal stone composition in phantom and patients using single-source dual-energy computed tomography. *J Comput Assist Tomogr.* 2013;37(1):37-45.
40. Li X, Zhao R, Liu B, Yu Y. Gemstone spectral imaging dual-energy computed tomography: a novel technique to determine urinary stone composition. *Urology.* 2013;81(4):727-730.
41. Boll DT, Patil NA, Paulson EK, et al. Renal stone assessment with dual-energy multidetector CT and advanced postprocessing techniques: improved characterization of renal stone composition--pilot study. *Radiology.* 2009;250(3):813-820.
42. Grosjean R, Sauer B, Guerra RM, et al. Characterization of human renal stones with MDCT: advantage of dual energy and limitations due to respiratory motion. *AJR Am J Roentgenol.* 2008;190(3):720-728.
43. Mangold S, Thomas C, Fenchel M, et al. Virtual nonenhanced dual-energy CT urography with tin-filter technology: determinants of detection of urinary calculi in the renal collecting system. *Radiology.* 2012;264(1):119-125.
44. Moon JW, Park BK, Kim CK, Park SY. Evaluation of virtual unenhanced CT obtained from dual-energy CT urography for detecting urinary stones. *Br J Radiol.* 2012;85(1014):e176-181.
45. Jung SI, Kim YJ, Park HS, et al. Sensitivity of digital abdominal radiography for the detection of ureter stones by stone size and location. *J Comput Assist Tomogr.* 2010;34(6):879-882.
46. Levine JA, Neitlich J, Verga M, Dalrymple N, Smith RC. Ureteral calculi in patients with flank pain: correlation of plain radiography with unenhanced helical CT. *Radiology.* 1997;204(1):27-31.
47. Ripolles T, Martinez-Perez MJ, Vizuete J, Miralles S, Delgado F, Pastor-Navarro T. Sonographic diagnosis of symptomatic ureteral calculi: usefulness of the twinkling artifact. *Abdom Imaging.* 2013;38(4):863-869.
48. 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(3):792-797.
49. Kielar AZ, Shabana W, Vakili M, Rubin J. Prospective evaluation of Doppler sonography to detect the twinkling artifact versus unenhanced computed tomography for identifying urinary tract calculi. *J Ultrasound Med.* 2012;31(10):1619-1625.
50. Rahmouni A, Bargoin R, Herment A, Bargoin N, Vasile N. Color Doppler twinkling artifact in hyperechoic regions. *Radiology.* 1996;199(1):269-271.
51. Fowler KA, Locken JA, Duchesne JH, Williamson MR. US for detecting renal calculi with nonenhanced CT as a reference standard. *Radiology.* 2002;222(1):109-113.
52. Ulasan S, Koc Z, Tokmak N. Accuracy of sonography for detecting renal stone: comparison with CT. *J Clin Ultrasound.* 2007;35(5):256-261.
53. Ripolles T, Agramunt M, Errando J, Martinez MJ, Coronel B, Morales M. Suspected ureteral colic: plain film and sonography vs unenhanced helical CT. A prospective study in 66 patients. *Eur Radiol.* 2004;14(1):129-136.
54. Varanelli MJ, Coll DM, Levine JA, Rosenfield AT, Smith RC. Relationship between duration of pain and secondary signs of obstruction of the urinary tract on unenhanced helical CT. *AJR Am J Roentgenol.* 2001;177(2):325-330.
55. Smith-Bindman R, Aubin C, Bailitz J, et al. Ultrasonography versus computed tomography for suspected nephrolithiasis. *N Engl J Med.* 2014;371(12):1100-1110.
56. Ekici S, Sinanoglu O. Comparison of conventional radiography combined with ultrasonography versus nonenhanced helical computed tomography in evaluation of patients with renal colic. *Urol Res.* 2012;40(5):543-547.
57. Amis ES, Jr., Cronan JJ, Pfister RC, Yoder IC. Ultrasonic inaccuracies in diagnosing renal obstruction. *Urology.* 1982;19(1):101-105.
58. Kamholtz RG, Cronan JJ, Dorfman GS. Obstruction and the minimally dilated renal collecting system: US evaluation. *Radiology.* 1989;170(1 Pt 1):51-53.
59. Kalb B, Sharma P, Salman K, Ogan K, Pattaras JG, Martin DR. Acute abdominal pain: is there a potential role for MRI in the setting of the emergency department in a patient with renal calculi? *J Magn Reson Imaging.* 2010;32(5):1012-1023.
60. Semins MJ, Feng Z, Trock B, Bohlman M, Hosek W, Matlaga BR. Evaluation of acute renal colic: a comparison of non-contrast CT versus 3-T non-contrast HASTE MR urography. *Urolithiasis.* 2013;41(1):43-46.
61. Regan F, Bohlman ME, Khazan R, Rodriguez R, Schultze-Haakh H. MR urography using HASTE imaging in the assessment of ureteric obstruction. *AJR Am J Roentgenol.* 1996;167(5):1115-1120.

62. Zielonko J, Studniarek M, Markuszewski M. MR urography of obstructive uropathy: diagnostic value of the method in selected clinical groups. *Eur Radiol.* 2003;13(4):802-809.
63. Yassin A, Pedrosa I, Kearney M, Genega E, Rofsky NM, Lenkinski RE. In vitro MR imaging of renal stones with an ultra-short echo time magnetic resonance imaging sequence. *Acad Radiol.* 2012;19(12):1566-1572.
64. Thoeny HC, Kessler TM, Simon-Zoula S, et al. Renal oxygenation changes during acute unilateral ureteral obstruction: assessment with blood oxygen level-dependent mr imaging--initial experience. *Radiology.* 2008;247(3):754-761.
65. Thoeny HC, Binsler T, Roth B, Kessler TM, Vermathen P. Noninvasive assessment of acute ureteral obstruction with diffusion-weighted MR imaging: a prospective study. *Radiology.* 2009;252(3):721-728.
66. Sudah M, Vanninen R, Partanen K, Heino A, Vainio P, Ala-Opas M. MR urography in evaluation of acute flank pain: T2-weighted sequences and gadolinium-enhanced three-dimensional FLASH compared with urography. Fast low-angle shot. *AJR Am J Roentgenol.* 2001;176(1):105-112.
67. Abramson S, Walders N, Applegate KE, Gilkeson RC, Robbin MR. Impact in the emergency department of unenhanced CT on diagnostic confidence and therapeutic efficacy in patients with suspected renal colic: a prospective survey. 2000 ARRS President's Award. American Roentgen Ray Society. *AJR Am J Roentgenol.* 2000;175(6):1689-1695.
68. Katz SI, Saluja S, Brink JA, Forman HP. Radiation dose associated with unenhanced CT for suspected renal colic: impact of repetitive studies. *AJR Am J Roentgenol.* 2006;186(4):1120-1124.
69. Broder J, Bowen J, Lohr J, Babcock A, Yoon J. Cumulative CT exposures in emergency department patients evaluated for suspected renal colic. *J Emerg Med.* 2007;33(2):161-168.
70. Sfoungaristos S, Gofrit ON, Katz R, et al. A predictive model for stone radiopacity in kidney-ureter-bladder film based on computed tomography parameters. *Urology.* 2014;84(5):1021-1025.
71. Wieseler KM, Bhargava P, Kanal KM, Vaidya S, Stewart BK, Dighe MK. Imaging in pregnant patients: examination appropriateness. *Radiographics.* 2010;30(5):1215-1229; discussion 1230-1213.
72. Masselli G, Derme M, Laghi F, et al. Imaging of stone disease in pregnancy. *Abdom Imaging.* 2013;38(6):1409-1414.
73. McAleer SJ, Loughlin KR. Nephrolithiasis and pregnancy. *Curr Opin Urol.* 2004;14(2):123-127.
74. Rasmussen PE, Nielsen FR. Hydronephrosis during pregnancy: a literature survey. *Eur J Obstet Gynecol Reprod Biol.* 1988;27(3):249-259.
75. White WM, Zite NB, Gash J, Waters WB, Thompson W, Klein FA. Low-dose computed tomography for the evaluation of flank pain in the pregnant population. *J Endourol.* 2007;21(11):1255-1260.
76. Roy C, Saussine C, Jahn C, et al. Fast imaging MR assessment of ureterohydronephrosis during pregnancy. *Magn Reson Imaging.* 1995;13(6):767-772.
77. Shokeir AA, El-Diasty T, Eassa W, et al. Diagnosis of ureteral obstruction in patients with compromised renal function: the role of noninvasive imaging modalities. *J Urol.* 2004;171(6 Pt 1):2303-2306.
78. Jaffe TA, Miller CM, Merkle EM. Practice patterns in imaging of the pregnant patient with abdominal pain: a survey of academic centers. *AJR Am J Roentgenol.* 2007;189(5):1128-1134.
79. American College of Radiology. ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation. Available at: [http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/Pregnant\\_Patients.pdf](http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/Pregnant_Patients.pdf). Accessed September 30, 2015.
80. American College of Radiology. ACR-ACOG-AIUM-SRU Practice Parameter for the Performance of Obstetrical Ultrasound. Available at: [http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/US\\_Obstetrical.pdf](http://www.acr.org/~media/ACR/Documents/PGTS/guidelines/US_Obstetrical.pdf). Accessed September 30, 2015.
81. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practices: 2013. *J Magn Reson Imaging.* 2013;37(3):501-530.
82. American College of Radiology. *Manual on Contrast Media.* Available at: <http://www.acr.org/~media/37D84428BF1D4E1B9A3A2918DA9E27A3.pdf>. Accessed September 30, 2015.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.