American College of Radiology
ACR Appropriateness Criteria®
Acute Onset Flank Pain-Suspicion of Stone Disease (Urolithiasis)

Variant: 1 Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
CT abdomen and pelvis without IV contrast	Usually Appropriate	☢☢☢
US color Doppler kidneys and bladder retroperitoneal	May Be Appropriate (Disagreement)	O
US kidneys and bladder retroperitoneal	May Be Appropriate (Disagreement)	O
Radiography abdomen and pelvis	May Be Appropriate	☢☢☢
Radiography intravenous urography	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O
MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	O
MRU without and with IV contrast	Usually Not Appropriate	O
MRU without IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CTU without and with IV contrast	Usually Not Appropriate	☢☢☢☢

Variant: 2 Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.

Procedure	Appropriateness Category	Relative Radiation Level
CT abdomen and pelvis without IV contrast	Usually Appropriate	☢☢☢
US color Doppler kidneys and bladder retroperitoneal	May Be Appropriate (Disagreement)	O
US kidneys and bladder retroperitoneal	May Be Appropriate	O
Radiography abdomen and pelvis	May Be Appropriate	☢☢☢
CT abdomen and pelvis with IV contrast	May Be Appropriate	☢☢☢
Radiography intravenous urography	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O
MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	O
MRU without and with IV contrast	Usually Not Appropriate	O
MRU without IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CTU without and with IV contrast	Usually Not Appropriate	☢☢☢☢

Variant: 3 Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.

Procedure	Appropriateness Category	Relative Radiation Level
US kidneys and bladder retroperitoneal	Usually Appropriate	O
US color Doppler kidneys and bladder retroperitoneal	May Be Appropriate (Disagreement)	O
MRU without IV contrast	May Be Appropriate	O
CT abdomen and pelvis without IV contrast	May Be Appropriate	☢☢☢
Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢

Radiography intravenous urography	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O
MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	O
MRU without and with IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CTU without and with IV contrast	Usually Not Appropriate	☢☢☢☢

<u>Variant: 4</u> Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.

Procedure	Appropriateness Category	Relative Radiation Level
MRU without and with IV contrast	May Be Appropriate	O
CT abdomen and pelvis with IV contrast	May Be Appropriate	☢☢☢
CTU without and with IV contrast	May Be Appropriate	☢☢☢☢
US color Doppler kidneys and bladder retroperitoneal	Usually Not Appropriate	O
US kidneys and bladder retroperitoneal	Usually Not Appropriate	O
Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢
Radiography intravenous urography	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O
MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	O
MRU without IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢

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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 60 years of age. For example, it is estimated that 19% of men and 9% of women will be diagnosed with a kidney stone by 70 years of age [1]. Stones also tend to be recurrent with recurrence rates shown to be higher in those with 2 or more previous stone episodes [2].

Owing to ureteral hyperperistalsis in the setting of a stone, a common presenting symptom of urolithiasis is flank pain, although this is nonspecific and associated with a variety of other entities.

Irritation of and trauma to the ureter may also result in hematuria. Ureteral obstruction with resultant hydronephrosis is a potential serious complication of stones. Treatment of urolithiasis may be conservative with supportive and medical therapy, although invasive therapies are required in some instances, most commonly via percutaneous nephrolithotomy, rigid and flexible ureteroscopy, or shock wave lithotripsy. Stone size and location have been shown to be important determinants in stone passage and the need for invasive management, with larger and more proximally located stones being associated with lower rates of spontaneous passage [3]. Given the often nonspecific presentation, imaging allows for the diagnosis of stones. Furthermore, imaging plays a larger role in assessment of alternative diagnoses, complications, and appropriateness of potential therapies [4]. Please note that this document on urolithiasis/acute flank pain and the variants it covers assumes that there are no clinical signs or suspicion of infection as renal infection is covered in a different topic (see the ACR Appropriateness Criteria® topic on "Acute Pyelonephritis" [5]).

Special Imaging Considerations

CT urography (CTU) is an imaging study that is tailored to improve visualization of both the upper and lower urinary tracts. There is variability in the specific parameters, but it usually involves unenhanced images followed by intravenous (IV) contrast-enhanced images, including nephrographic and excretory phases acquired at least 5 minutes after contrast injection. Alternatively, a split-bolus technique uses an initial loading dose of IV contrast and then obtains a combined nephrographic-excretory phase after a second IV contrast dose; some sites include arterial phase. CTU should use thin-slice acquisition. Reconstruction methods commonly include maximum intensity projection or 3-D volume rendering. For the purposes of this document, we make a distinction between CTU and CT abdomen and pelvis without and with IV contrast. CT abdomen and pelvis without and with IV contrast is defined as any protocol not specifically tailored for the evaluation of the upper and lower urinary tracts and without both the precontrast and excretory phases.

In an effort to minimize patient radiation dose, low-dose CT examinations can replace traditional noncontrast CT examinations and are often performed using a combination of lowering milliampere-seconds, kilovoltage peak, and scan range. Dual-energy CT allows for the characterization of stone composition (ie, uric acid, cystine, and calcium) and the generation of virtual unenhanced images simulating noncontrast CT images [6-8].

MR urography (MRU) is also tailored to improve visualization of the urinary system. Unenhanced MRU relies upon the intrinsic high signal intensity from urine on heavily T2-weighted imaging for the evaluation of the urinary tract. IV contrast is administered to provide additional information regarding obstruction, urothelial thickening, focal lesions, and stones. Contrast-enhanced T1-weighted series should include corticomedullary, nephrographic, and excretory phases. Thin-slice acquisition and multiplanar imaging should be obtained. For the purposes of this document, we make a distinction between MRU and MRI abdomen and pelvis without and with IV contrast. MRI abdomen and pelvis without and with IV contrast is defined as any MRI protocol not specifically tailored for evaluation of the upper and lower urinary tracts, without both the precontrast and excretory phases, and without heavily T2-weighted images of the urinary tract.

The addition of digital tomosynthesis (DT) to standard digital radiography allows for additional radiographic projections at multiple angles, thus removing overlying structures and providing depth information about stones compared with 2-D radiographs. Compared with noncontrast CT, DT has demonstrated similar intrarenal stone detection rates with respect to stone counts and stone area [9]. In another study, for intrarenal stones, radiography covering the kidneys, ureters, and bladder (KUB) with DT was significantly more accurate than KUB alone (81% versus 48%), with no difference seen between KUB with DT and CT (81% versus 81%). However, in an ex vivo study, accuracy for ureteral stones was lower, with an identification rate of only 24% with KUB and DT, although it was significantly higher than that with KUB alone (13%) [10]. It should be noted that at the time of writing, DT is not available/widely used at many institutions.

Lastly, for the purposes of this document, ultrasound (US) examinations for urolithiasis are assumed to include both grayscale and targeted use of color Doppler images for nonvascular assessment, the latter allowing for the assessment of twinkling artifact, appearing as an intense multicolored signal deep to a stone [11].

Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.

A. CT Abdomen and Pelvis With IV Contrast

CT abdomen and pelvis with IV contrast is commonly obtained with the contrast phase targeted for the portal venous or nephrographic phase. The presence of enhancing renal parenchyma during this phase of contrast may obscure stones within the renal collecting system, and therefore CT abdomen and pelvis with IV contrast is usually not appropriate as a first-line test in the evaluation of the patient with acute onset flank pain and suspicion of stone disease. It should be noted that the presence of IV contrast; however, may better delineate a "soft tissue rim" sign that may help differentiate a ureteral stone from a phlebolith and enhance detection of urinary obstruction by the presence of a delayed nephrogram. The use of contrast-enhanced CT also allows for the evaluation of other etiologies of flank pain. Contrast-enhanced CT in the portal venous phase has been shown to be 81% sensitive overall for the detection of all (≥1 mm) renal stones when compared with noncontrast CT, with improved performance for larger stones (eg, 95% sensitivity for stones ≥3 mm) [12]. The phase of enhancement (ie, corticomedullary versus nephrographic) has not been shown to affect stone detection rate [13]. Additionally, the use of thick (5 mm) coronal maximum intensity projection images in this setting did not improve renal stone detection compared with thin (1-1.5 mm) axial slice images [14]. It should be noted that although noncontrast CT allows for evaluating urolithiasis, should the patient have undergone a CT abdomen and pelvis with IV contrast, studies show that the detectability of renal stones ≥6 mm on contrast-enhanced CT is extremely high (approximately 98%); therefore, stones with a higher risk of not passing spontaneously can be safely diagnosed on contrast-enhanced CT [13].

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
B. CT Abdomen and Pelvis Without and With IV Contrast

In the genitourinary system, CT abdomen and pelvis without and with IV contrast is commonly performed to evaluate for the presence of enhancement within a renal lesion such as a cyst or mass. There is no relevant literature documenting the additional benefit of nonexcretory phase postcontrast CT in addition to noncontrast CT in the evaluation of urolithiasis.

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
C. CT Abdomen and Pelvis Without IV Contrast

Virtually all renal calculi are radiopaque on CT, allowing for accurate detection of even small stones at CT without the use of IV contrast. CT allows for rapid acquisition with high spatial resolution and ability for multiplanar reformations. Secondary signs of urolithiasis and complications such as periureteral and perinephric inflammation and ureteral dilatation can also be visualized with noncontrast CT. With a reported sensitivity as high as 97%, noncontrast CT is currently considered the reference standard for the evaluation of urolithiasis [15,16]. Despite this high demonstrated accuracy, a recent study demonstrated a decreased number of calculi detected at noncontrast CT when compared with endoscopy (9.2 versus 5.9 stones per kidney, respectively) [17]. Concerns over radiation exposure, especially in young patients, and increased attention to "as low as reasonably achievable" radiation principles have led to increased use of low-dose noncontrast CT for stone assessment. 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% [17]. The sensitivity for stone detection decreases with smaller stone size. The sensitivity for small stones can be further hampered with increasing dose reduction [18]. Low-dose CT has also been shown to yield equivalent stone measurements compared with standard-dose CT [19].

Stone location and size can be accurately depicted at noncontrast CT and have also been associated with spontaneous stone passage rates, with more proximal as well as larger stones having a higher need for intervention [3]. Furthermore, larger stone size and higher density measured at CT have also been shown to be predictors of the need for invasive management [20]. CT allows for accurate assessment of stone size, which is important in planning urologic management. CT techniques shown to improve accuracy of stone measurements include use of coronal reformations, viewing on bone window, and use of magnified views [21-23]. Lastly, noncontrast CT has also shown utility in aiding in diagnosis of flank pain other than urolithiasis [24].

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
D. CTU Without and With IV Contrast

CTU involves the addition of a delayed, excretory phase images that opacifies the upper and lower urinary tracts and allows for more complete evaluation of these structures relative to nonurogram CT techniques. With urinary tract opacification, CTU confirms the ureteral location of a calculus, distinguishing from stone mimics such as an adjacent phlebolith. CTU can better confirm the degree of obstruction caused by a ureteral stone and potentially also aid in diagnosing a radiolucent stone, albeit a rare entity. However, there is no relevant literature documenting a difference in accuracy of additional excretory phase postcontrast imaging relative to noncontrast CT alone in the evaluation of urolithiasis.

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
E. MRI Abdomen and Pelvis Without and With IV Contrast

MRI abdomen and pelvis without and with IV contrast is defined as any MRI protocol not specifically tailored for evaluation of the upper and lower urinary tracts, without both the precontrast and excretory phases, and without heavily T2-weighted images of the urinary tract. There is limited literature on the use of MRI abdomen and pelvis without and with IV contrast in the evaluation of the patient with suspected urolithiasis; however, in one study, T2-weighted imaging has been shown to improve sensitivity of detection of perirenal fluid in the setting of acute calculus ureteric obstruction compared with fat stranding on unenhanced CT (77% versus 45%, respectively) [25]. In another study, also in the setting of acute ureteric obstruction, both excretory urography and T2-weighted MRI showed obstruction in a high percentage of cases [26]. There is no relevant literature documenting the additional benefit of MRI abdomen and pelvis with IV contrast in the nonexcretory phase in a patient with acute flank pain and suspicion of stone disease.

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
F. MRI Abdomen and Pelvis Without IV Contrast

MRI abdomen and pelvis without IV contrast is defined as any MRI protocol not specifically tailored for evaluation of the upper and lower urinary tracts, which includes precontrast imaging but does not include heavily T2-weighted images of the urinary tract. There is limited literature on the use of MRI abdomen and pelvis without and with IV contrast in the evaluation of the patient with suspected urolithiasis; however, in one study, T2-weighted imaging has been shown to improve sensitivity of detection of perirenal fluid in the setting of acute calculus ureteric obstruction compared with fat stranding on unenhanced CT (77% versus 45%, respectively) [25]. In another study, also in the setting of acute ureteric obstruction, both excretory urography and T2-weighted MRI showed obstruction in a high percentage of cases [26].

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
G. MRU Without and With IV Contrast

MRU is an alternative means of obtaining cross-sectional, excretory phase images without the use of iodinated contrast. Limited studies are available detailing the utility of contrast-enhanced MRU in the detection of urolithiasis. In a study published in 2001, the use of gadolinium-enhanced 3-D fast low-angle shot MRU was shown to provide higher sensitivity in detection of stones compared with noncontrast MR technique (heavily T2-weighted; combined thin-slice half-Fourier acquisition single-shot turbo spin-echo and thick-slab single-shot turbo spin-echo; 96%-100% versus 54%-58%, respectively) [27]. Owing to its superior detection of fluid with T2-weighted sequences, MRU has been shown to be more sensitive than noncontrast CT in the detection of secondary signs of obstruction in the presence of urolithiasis such as hydronephrosis and perinephric fluid [28].

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
H. MRU Without IV Contrast

MRU can also evaluate the urinary system without the use of IV contrast. In an early study performed in patients with acutely obstructed kidneys, noncontrast MRU was found to be 100% sensitive for diagnosing obstruction with perirenal fluid seen in 87% of cases, with the site of the obstruction seen in 80% of these obstructed kidneys. In an early study, when referenced to IVU, corresponding filling defects at MRU were seen in 12 of 18 patients with ureteric obstruction caused by a stone ranging from 4 to 20 mm in size [26]. In a more recent study performed at 3T, in patients presenting with renal colic, noncontrast MRU only detected stones in 50% of patients compared with 91% with noncontrast CT. However, the combination of stone or perinephric fluid and ureteral dilation gave MRU a sensitivity of 84%, specificity of 100%, and accuracy of 86% for stone detection when compared with CT [28].

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
I. Radiography abdomen and pelvis

KUB 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, and these entities may be difficult to distinguish on a single 2-D view. Factors influencing the sensitivity of KUB for urolithiasis include stone composition, location, and size, as well as patient body habitus and overlying bowel contents. When compared with noncontrast CT as the reference standard, digital radiography has been shown 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 [29]. In a more recent study, KUB detected only 8% of stones ≤5 mm relative to noncontrast CT, although a detection rate of 78% at KUB was observed overall for stones >5 mm [30].

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
J. Radiography Intravenous Urography

IV urography (IVU) was once considered the reference standard for the diagnosis of urolithiasis. With the administration of contrast, IVU provides additional information beyond radiography including structural and functional information about kidneys, ureters, and urinary bladder, including the site and degree of obstruction from urolithiasis. A study comparing IVU with noncontrast CT demonstrated a sensitivity and specificity of IVU to be 75% and 92%, respectively, compared with 85% and 98%, respectively, at noncontrast CT [31]. Another study demonstrated significantly greater performance of noncontrast CT over IVU with sensitivities and specificities of 96% and 100%, respectively, for CT versus 87% and 94%, respectively, for IVU [32].

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
K. US Color Doppler Kidneys and Bladder Retroperitoneal

There is no evidence to support the use of dedicated US color Doppler in the evaluation of patients with acute onset flank pain and suspicion for urolithiasis and with no history of stone disease. This procedure is intended for evaluation of vasculature.

Variant 1: Acute onset flank pain. Suspicion of stone disease. No history or remote history of stone disease. Initial imaging.
L. US Kidneys and Bladder Retroperitoneal

Using grayscale techniques, US demonstrates variable performance in the detection of renal calculi depending on the clinical scenario and associated complications. Compared with noncontrast CT, initial studies evaluating grayscale US demonstrated an overall sensitivity of 24% to 57% for stone detection with decreased sensitivity for smaller stones [33,34]. Detection of ureteral calculi is also reduced compared with CT, demonstrating sensitivity up to 61% with a specificity of 100%, although sensitivity is improved if there are associated signs of obstruction [16]. Stone size estimation at US is also limited compared with CT, particularly with smaller (≤5 mm) stones, with a tendency of US to overestimate stone size [35,36].

US has been found to be up to 100% sensitive and 90% specific for the diagnosis of ureteral obstruction (hydronephrosis, ureterectasis, and perinephric fluid) in patients presenting with acute flank pain [37]. However, within the first 2 hours of presentation, these findings are less sensitive because secondary signs of obstruction may not have had time to develop [38]. Furthermore, although hydronephrosis on US does not accurately predict the presence or absence of a ureteral stone on computerized tomography in up to 25% of patients [39], it has been shown that in an US-first approach, the lack of hydronephrosis on US makes the presence of a larger ureteral stone (>5 mm) less likely [40].

The addition of color Doppler and assessment of twinkling artifact has been shown to provide higher sensitivity, particularly for small renal stones, with described sensitivity reported as high as 99% for stones <5 mm in patients with lumbar pain or history of renal stones [11]. However, twinkling artifact is prone to false-positives, with a false-positive rate reported up to 60% [41]. Also, the performance of color Doppler is influenced by stone site and diameter [42]. It should be noted that the targeted use of Doppler for nonvascular assessment does not constitute a full Doppler examination.

US can also be combined with radiography to improve stone detection and has been pursued as an alternative to CT, particularly for the detection of clinically significant stones. In a prospective study of 66 patients, the combination of US and radiography demonstrated a sensitivity of 79% (versus 93% for noncontrast CT) for detecting stones. However, in this series, all missed cases had spontaneous stone passage, in which case noncontrast CT may not have added useful information [37]. In a more recent study, the combination of US and radiography yielded a sensitivity of 90% and specificity of 68%, with decreased detection rates for stones <5 mm [30].

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
A. CT Abdomen and Pelvis With IV Contrast

The presence of IV contrast in the portal or nephrographic phase may better delineate a "soft tissue rim” sign that may help differentiate a ureteral stone from a phlebolith. Opacification of the iliac vessels allows confirmation of iliac arterial calcifications, which can mimic distal ureteral stones. Furthermore, a delayed nephrogram in the setting of obstruction from a ureteral stone may be detected with IV contrast in this phase. However, there is no relevant literature documenting the additional benefit of a nonexcretory phase postcontrast CT in a patient with known current stone disease, diagnosed on recent imaging with recurrent symptoms of stone disease. The use of contrast-enhanced CT does also allow for the evaluation of other etiologies of flank pain [43]. In studies evaluating the use of CT abdomen and pelvis with IV contrast following a noncontrast CT, contrast-enhanced CT provided additional information or revealed a new diagnosis in 5% to 18% of cases, while ultimately changing clinical management in only 2% to 3% of cases [44,45].

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
B. CT Abdomen and Pelvis Without and With IV Contrast

There is no relevant literature documenting the additional benefit of repeat noncontrast CT followed by CT abdomen and pelvis with IV contrast in a patient with known current stone disease, diagnosed on recent imaging with recurrent symptoms of stone disease.

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
C. CT Abdomen and Pelvis Without IV Contrast

The patient with known current stone disease, diagnosed on recent imaging, with recurrent symptoms of stone disease is more likely to have urolithiasis as the etiology of flank pain than other etiologies. As such, it is important to assess if symptoms are related to interval stone migration or passage as opposed to complications of urolithiasis such as infection, perinephric abscess, urinoma, etc.

Similar to Variant 1, noncontrast CT is currently considered the reference standard for the evaluation of urolithiasis, with a reported sensitivity as high as 97% [15,16]. The key consideration in repeat studies of patients with urolithiasis is by optimizing dose in each study and reducing the overall number of imaging studies to the lowest number possible.

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
D. CTU Without and With IV Contrast

With urinary tract opacification, CTU confirms the ureteral location of a calculus, distinguishing from stone mimics such as an adjacent phlebolith or vascular calcification. CTU can better confirm the degree of obstruction caused by a ureteral stone and potentially also aid in diagnosing a radiolucent stone that may not be visualized with noncontrast CT. However, there is no relevant literature documenting the benefit of additional CTU in a patient with known current stone disease, diagnosed on recent imaging with recurrent symptoms of stone disease.

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
E. MRI Abdomen and Pelvis Without and With IV Contrast

There is no relevant literature documenting the additional benefit of MRI without and with IV contrast in a patient with known current stone disease, diagnosed on recent imaging with recurrent symptoms of stone disease.

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on

recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
F. MRI Abdomen and Pelvis Without IV Contrast

There is no relevant literature documenting the additional benefit of MRI without IV contrast in a patient with known current stone disease, diagnosed on recent imaging with recurrent symptoms of stone disease.

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
G. MRU Without and With IV Contrast

There is no relevant literature documenting the additional benefit of MRU without and with IV contrast in a patient with known current stone disease, diagnosed on recent imaging with recurrent symptoms of stone disease. However, MRU has been shown in the setting of initial stone detection to be more sensitive than noncontrast CT in the detection of secondary signs of obstruction in the presence of urolithiasis, although this has not been specifically assessed in this clinical scenario [28].

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
H. MRU Without IV Contrast

There is no relevant literature documenting the additional benefit of MRU without IV contrast in a patient with known current stone disease, diagnosed on recent imaging with recurrent symptoms of stone disease.

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
I. Radiography abdomen and pelvis

If a stone was initially radiopaque on initial KUB and/or CT, a follow-up KUB could indicate whether a stone has migrated/changed in position. However, there is no relevant literature documenting the benefit of KUB in a patient with known current stone disease, diagnosed on recent imaging with recurrent symptoms of stone disease.

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
J. Radiography Intravenous Urography

With urinary tract opacification, IVU may confirm the ureteral location of a calculus, distinguishing from stone mimics such as an adjacent phlebolith or vascular calcification. However, there is no relevant literature specifically assessing its use/benefit in this clinical scenario.

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
K. US Color Doppler Kidneys and Bladder Retroperitoneal

There is no evidence to support the use of dedicated US color Doppler in the evaluation of patients with known current stone disease, diagnosed on recent imaging with recurrent symptoms of stone disease. This procedure is intended for evaluation of vasculature.

Variant 2: Acute onset flank pain in patient with known current stone disease, diagnosed on recent imaging. Recurrent symptoms of stone disease. Follow-up imaging.
L. US Kidneys and Bladder Retroperitoneal

US Kidneys and Bladder Retroperitoneal

Using grayscale techniques, US demonstrates variable performance in the detection of renal calculi depending on the clinical scenario but is used to assess for associated complications such as hydronephrosis. In one study, using US to guide clinical decision-making for patients with known residual calculi is limited by low sensitivity and the inability to size the stone accurately, which can lead to inappropriate counseling for patients [36].

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.

Stones can be a source of abdominal pain in pregnant patients. Urolithiasis can also be associated with hydronephrosis if there is a component of obstruction; 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 [46]. Physiologic hydronephrosis of pregnancy occurs in >80% of pregnant patients, more commonly occurs on the right than the left, and is generally seen beginning in the second trimester [46].

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
A. CT Abdomen and Pelvis With IV Contrast

There is no relevant literature documenting the additional benefit of CT abdomen and pelvis with IV contrast, relative to noncontrast CT, in the pregnant patient for the evaluation of stones.

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
B. CT Abdomen and Pelvis Without and With IV Contrast

There is no relevant literature documenting the additional benefit of CT abdomen and pelvis without and with IV contrast, relative to noncontrast CT alone, in the pregnant patient for the evaluation of stones.

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
C. CT Abdomen and Pelvis Without IV Contrast

CT abdomen and pelvis without IV contrast has been shown to be a sensitive and specific test for diagnosing stones in pregnant patients [47]. The key consideration in CT studies for pregnant patients with suspected urolithiasis is mitigating effects of radiation dose by optimizing dose in each study and reducing the overall number of imaging studies to the lowest number possible.

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
D. CTU Without and With IV Contrast

There is no relevant literature documenting the additional benefit of CTU without and with IV contrast, relative to noncontrast CT alone, in the pregnant patient for the evaluation of stones.

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
E. MRI Abdomen and Pelvis Without IV Contrast

There is no relevant literature documenting the additional benefit of MRI without IV contrast without dedicated urographic imaging, relative to noncontrast MRU, in the pregnant patient for the evaluation of stones; however, it can be helpful in follow-up imaging for stones and/or hydronephrosis, particularly if US is limited.

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
F. MRI Abdomen and Pelvis Without and With IV Contrast

There is no relevant literature documenting the additional benefit of MRI without and with IV contrast, relative to noncontrast MRU, in the pregnant patient for the evaluation of stones.

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
G. MRU Without and With IV Contrast

There is no relevant literature documenting the additional benefit of MRU without and with IV contrast, relative to noncontrast MRU, in the pregnant patient for the evaluation of stones.

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
H. MRU Without IV Contrast

With a goal of avoiding irradiation of the fetus, MRU has also been advocated for the detection of ureteral calculi at some centers [48] as well as hydronephrosis or other cause of renal obstruction. However, in a study by Shokeir et al [49] 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 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 [50].

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
I. Radiography abdomen and pelvis

There is no relevant literature documenting the benefit of KUB in the pregnant patient for the evaluation of stones.

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
J. Radiography Intravenous Urography

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 [51].

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
K. US Color Doppler Kidneys and Bladder Retroperitoneal

There is no evidence to support the use of dedicated US color Doppler in the evaluation of pregnant patients with suspicion of stone disease. This procedure is intended for evaluation of vasculature.

Variant 3: Pregnant patient. Acute onset flank pain. Suspicion of stone disease. Initial or follow-up imaging.
L. US Kidneys and Bladder Retroperitoneal

US is frequently used as a screening examination, because US is a sensitive and specific test for diagnosing hydronephrosis and does not expose the patient or fetus to ionizing radiation [52-54].

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.

In clinical practice, a noncontract CT may be inconclusive for stones when it is unclear whether an identified calcification is located within the ureter or an adjacent structure. Common mimics of ureteral stones include phleboliths or arterial calcifications. This uncertainty can be exacerbated in thin patients with a lack of sufficient fat planes separating the ureters from adjacent structures.

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
A. CT Abdomen and Pelvis With IV Contrast

The presence of IV contrast in the portal or nephrographic phase may better delineate a "soft tissue rim” sign that may help differentiate a ureteral stone from a phlebolith. Opacification of the iliac vessels allows confirmation of iliac arterial calcifications, which can mimic distal ureteral stones. Furthermore, a delayed nephrogram in the setting of obstruction from a ureteral stone may be detected with IV contrast in this phase. However, there is no relevant literature documenting the additional benefit of a nonexcretory phase postcontrast CT in a patient with known current stone disease, diagnosed on recent imaging with recurrent symptoms of stone disease. The use of contrast-enhanced CT does also allow for the evaluation of other etiologies of flank pain [43]. In studies evaluating the use of CT abdomen and pelvis with IV contrast following a noncontrast CT, contrast-enhanced CT provided additional information or revealed a new diagnosis in 5% to 18% of cases, while ultimately changing clinical management in only 2% to 3% of cases [44,45].

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
B. CT Abdomen and Pelvis Without and With IV Contrast

There is no relevant literature documenting the additional benefit of repeat noncontrast CT followed by CT abdomen and pelvis with IV contrast after an inconclusive CT without IV contrast in the evaluation of stones.

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
C. CT Abdomen and Pelvis Without IV Contrast

There is no relevant literature documenting the additional benefit of repeat noncontrast CT after an inconclusive CT without IV contrast in the evaluation of stones.

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
D. CTU Without and With IV Contrast

With urinary tract opacification, CTU confirms the ureteral location of a calculus, distinguishing from stone mimics such as an adjacent phlebolith or vascular calcification. CTU can better confirm the degree of obstruction caused by a ureteral stone and potentially also aid in diagnosing a radiolucent stone that may not be visualized with noncontrast CT and can also detect urothelial masses on the excretory phase. However, there is no relevant literature documenting the additional benefit of additional CTU after an inconclusive CT without IV contrast in the evaluation of stones.

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
E. MRI Abdomen and Pelvis Without and With IV Contrast

There is no relevant literature documenting the additional benefit of MRI without and with IV contrast after an inconclusive CT without IV contrast in the evaluation of stones.

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
F. MRI Abdomen and Pelvis Without IV Contrast

There is no relevant literature documenting the additional benefit of MRI without IV contrast after an inconclusive CT without IV contrast in the evaluation of stones.

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
G. MRU Without and With IV Contrast

There is no relevant literature documenting the additional benefit of MRU without and with IV contrast after an inconclusive CT without IV contrast in the evaluation of stones. However, MRU has been shown in the setting of initial stone detection to be more sensitive than noncontrast CT in the detection of secondary signs of obstruction in the presence of urolithiasis, although this has not been specifically assessed in this clinical scenario [28].

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
H. MRU Without IV Contrast

There is no relevant literature documenting the additional benefit of MRU without IV contrast after an inconclusive CT without IV contrast in the evaluation of stones.

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
I. Radiography abdomen and pelvis

There is no relevant literature documenting the additional benefit of KUB after an inconclusive CT without IV contrast in the evaluation of stones.

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
J. Radiography Intravenous Urography

With urinary tract opacification, IVU may confirm the ureteral location of a calculus, distinguishing from stone mimics such as an adjacent phlebolith or vascular calcification. However, there is no relevant literature documenting the additional benefit of IVU after an inconclusive CT without IV contrast in the evaluation of stones.

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
K. US Color Doppler Kidneys and Bladder Retroperitoneal

There is no evidence to support the use of dedicated US color Doppler after an inconclusive CT without IV contrast in the evaluation of stones. This procedure is intended for the evaluation of vasculature.

Variant 4: Acute onset flank pain. Suspicion of stone disease. CT without contrast is inconclusive for the presence of stones. Next imaging study.
L. US Kidneys and Bladder Retroperitoneal

There is no relevant literature documenting the additional benefit of US after an inconclusive CT without IV contrast in the evaluation of stones.

Summary of Recommendations

- **Variant 1**: CT abdomen and pelvis without IV contrast is usually appropriate for the initial imaging of acute onset flank pain and suspicion for urolithiasis and with no history or remote history of stone disease. Although the panel did not agree on recommending US color Doppler kidneys and bladder retroperitoneal or US kidneys and bladder retroperitoneal because there is insufficient medical literature to conclude whether these patients would benefit from the procedure, its use may be appropriate.
- **Variant 2**: In the setting of acute onset flank pain with known current stone disease that was diagnosed on recent imaging, CT abdomen and pelvis without IV contrast is usually appropriate as the follow-up imaging for recurrent symptoms of stone disease. Although the panel did not agree on recommending US color Doppler kidneys and bladder retroperitoneal because there is insufficient medical literature to conclude whether these patients would benefit from the procedure, its use and the use of CT abdomen and pelvis with IV contrast may be appropriate.
- **Variant 3**: US kidneys and bladder retroperitoneal is usually appropriate for the initial or follow-up imaging of pregnant patients with acute onset flank pain and suspicion of stone disease. Although the panel did not agree on recommending US color Doppler kidneys and bladder retroperitoneal because there is insufficient medical literature to conclude whether these patients would benefit from the procedure, its use as well as the use of MRU without IV contrast or CT abdomen and pelvis without IV contrast may be appropriate.
- **Variant 4**: In the setting of acute onset flank pain and suspicion of stone disease, MRU without and with IV contrast or CT abdomen and pelvis with IV contrast or CTU without and with IV contrast may be appropriate as the next imaging study when CT without IV contrast is inconclusive for the presence of stones.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

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 the Safe and Optimal Performance of Fetal Magnetic Resonance Imaging (MRI) [55]
- ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation [56]

- ACR-ACOG-AIUM-SMFM-SRU Practice Parameter for the Performance of Standard Diagnostic Obstetrical Ultrasound [57]
- ACR Manual on Contrast Media [58]
- ACR Manual on MR Safety [59]

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

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, because of both 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 with 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 [60].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate**	**Pediatric Effective Dose Estimate Range**

	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.”		

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