

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

**Variant: 1 Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US abdomen	Usually Not Appropriate	○
US color Doppler kidneys and bladder retroperitoneal	Usually Not Appropriate	○
Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☼☼
Fluoroscopy antegrade pyelography	Usually Not 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	○
MRI abdomen and pelvis without IV contrast	Usually Not Appropriate	○
MRI abdomen without and with IV contrast	Usually Not Appropriate	○
MRI abdomen without IV contrast	Usually Not Appropriate	○
MRU without and with IV contrast	Usually Not Appropriate	○
MRU without IV contrast	Usually Not Appropriate	○
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☼☼☼
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☼☼☼
CT abdomen with IV contrast	Usually Not Appropriate	☼☼☼
CT abdomen without IV contrast	Usually Not Appropriate	☼☼☼
DMSA renal scan	Usually Not Appropriate	☼☼☼
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☼☼☼☼
CT abdomen without and with IV contrast	Usually Not Appropriate	☼☼☼☼
CTU without and with IV contrast	Usually Not Appropriate	☼☼☼☼

**Variant: 2 Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CT abdomen and pelvis with IV contrast	Usually Appropriate	☼☼☼
US abdomen	May Be Appropriate	○
US color Doppler kidneys and bladder retroperitoneal	May Be Appropriate	○
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	○
MRI abdomen and pelvis without IV contrast	May Be Appropriate	○
CT abdomen and pelvis without IV contrast	May Be Appropriate	☼☼☼
CT abdomen with IV contrast	May Be Appropriate (Disagreement)	☼☼☼
CT abdomen and pelvis without and with IV contrast	May Be Appropriate (Disagreement)	☼☼☼☼
Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☼☼
Fluoroscopy antegrade pyelography	Usually Not Appropriate	☼☼☼

Radiography abdomen and pelvis	Usually Not Appropriate	☼☼☼
Radiography intravenous urography	Usually Not Appropriate	☼☼☼
MRI abdomen without and with IV contrast	Usually Not Appropriate	○
MRI abdomen without IV contrast	Usually Not Appropriate	○
MRU without and with IV contrast	Usually Not Appropriate	○
MRU without IV contrast	Usually Not Appropriate	○
CT abdomen without IV contrast	Usually Not Appropriate	☼☼☼
DMSA renal scan	Usually Not Appropriate	☼☼☼
CT abdomen without and with IV contrast	Usually Not Appropriate	☼☼☼☼
CTU without and with IV contrast	Usually Not Appropriate	☼☼☼☼

**Variant: 3 Suspected acute pyelonephritis. History of renal stones or renal obstruction.**

**Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CT abdomen and pelvis with IV contrast	Usually Appropriate	☼☼☼
CT abdomen and pelvis without and with IV contrast	Usually Appropriate	☼☼☼☼
US abdomen	May Be Appropriate	○
US color Doppler kidneys and bladder retroperitoneal	May Be Appropriate	○
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	○
MRI abdomen and pelvis without IV contrast	May Be Appropriate	○
CT abdomen and pelvis without IV contrast	May Be Appropriate	☼☼☼
CT abdomen without and with IV contrast	May Be Appropriate (Disagreement)	☼☼☼☼
Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☼☼
Fluoroscopy antegrade pyelography	Usually Not Appropriate	☼☼☼
Radiography abdomen and pelvis	Usually Not Appropriate	☼☼☼
Radiography intravenous urography	Usually Not Appropriate	☼☼☼
MRI abdomen without and with IV contrast	Usually Not Appropriate	○
MRI abdomen without IV contrast	Usually Not Appropriate	○
MRU without and with IV contrast	Usually Not Appropriate	○
MRU without IV contrast	Usually Not Appropriate	○
CT abdomen with IV contrast	Usually Not Appropriate	☼☼☼
CT abdomen without IV contrast	Usually Not Appropriate	☼☼☼
DMSA renal scan	Usually Not Appropriate	☼☼☼
CTU without and with IV contrast	Usually Not Appropriate	☼☼☼☼

**Variant: 4 Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US abdomen	May Be Appropriate (Disagreement)	○
US color Doppler kidneys and bladder retroperitoneal	May Be Appropriate	○
MRI abdomen and pelvis without IV contrast	May Be Appropriate	○
MRI abdomen without IV contrast	May Be Appropriate	○
MRU without IV contrast	May Be Appropriate	○

Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☠☠
Fluoroscopy antegrade pyelography	Usually Not 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	○
MRI abdomen without and with IV contrast	Usually Not Appropriate	○
MRU without and with IV contrast	Usually Not Appropriate	○
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☠☠☠
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☠☠☠
CT abdomen with IV contrast	Usually Not Appropriate	☠☠☠
CT abdomen without IV contrast	Usually Not Appropriate	☠☠☠
DMSA renal scan	Usually Not Appropriate	☠☠☠
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☠☠☠☠
CT abdomen without and with IV contrast	Usually Not Appropriate	☠☠☠☠
CTU without and with IV contrast	Usually Not Appropriate	☠☠☠☠

**Variant: 5 Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US duplex Doppler kidney transplant	Usually Appropriate	○
CT abdomen and pelvis with IV contrast	Usually Appropriate	☠☠☠
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	○
MRI abdomen and pelvis without IV contrast	May Be Appropriate	○
CT abdomen and pelvis without IV contrast	May Be Appropriate	☠☠☠
CT abdomen and pelvis without and with IV contrast	May Be Appropriate	☠☠☠☠
US abdomen	Usually Not Appropriate	○
US color Doppler kidneys and bladder retroperitoneal	Usually Not Appropriate	○
Fluoroscopy voiding cystourethrography	Usually Not Appropriate	☠☠
Fluoroscopy antegrade pyelography	Usually Not Appropriate	☠☠☠
Radiography abdomen and pelvis	Usually Not Appropriate	☠☠☠
Radiography intravenous urography	Usually Not Appropriate	☠☠☠
MRI abdomen without and with IV contrast	Usually Not Appropriate	○
MRI abdomen without IV contrast	Usually Not Appropriate	○
MRI pelvis without and with IV contrast	Usually Not Appropriate	○
MRI pelvis without IV contrast	Usually Not Appropriate	○
MRU without and with IV contrast	Usually Not Appropriate	○
MRU without IV contrast	Usually Not Appropriate	○
CT abdomen with IV contrast	Usually Not Appropriate	☠☠☠
CT abdomen without IV contrast	Usually Not Appropriate	☠☠☠
DMSA renal scan	Usually Not Appropriate	☠☠☠
CT abdomen without and with IV contrast	Usually Not Appropriate	☠☠☠☠
CTU without and with IV contrast	Usually Not Appropriate	☠☠☠☠

## Panel Members

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## Summary of Literature Review

### Introduction/Background

Acute pyelonephritis (APN) is a severe urinary tract infection (UTI) that has the potential to cause sepsis, shock, and death [1]. The annual incidence of APN is 459,000 to 1,128,000 cases in the United States and 10.5 to 25.9 million cases globally [1,2]. The term pyelonephritis implies that there is inflammation of the renal pelvis and kidney. APN often presents with signs and symptoms of both systemic inflammation (eg, fever, chills, and fatigue) and bladder inflammation (eg, urgency, dysuria, and urinary frequency) [1]. There is a surprising lack of consensus regarding diagnostic criteria, and differentiation from infections of the lower urinary tract can be difficult [1]. Clinical presentation of APN can range from mild flank pain with low-grade or no fever to septic shock, and up to 20% of patients lack bladder symptoms. In patients with flank pain or tenderness, without or with voiding symptoms, without or with fever, and with a urinalysis showing pyuria and/or bacteriuria, APN is an appropriate presumptive diagnosis [1]. In this setting, urine cultures yielding >10,000 colony-forming units of a uropathogen per milliliter of urine is the fundamental confirmatory diagnostic test. Positive blood cultures may assist with the diagnosis.

In young healthy women, *Escherichia coli* accounts for more than 90% of APN cases [1,3]. However, in men, elderly women, and urologically compromised and institutionalized patients, less-virulent *E. coli* strains, gram-negative bacilli, gram-positive organisms, and candida are also common [1,4]. Risk factors for cystitis predispose to APN and include sexual activity, new sexual partner, spermicide exposure, personal or maternal history of UTIs, genetic predisposition, and diabetes mellitus [1,5]. Fortunately, <3% of cases of cystitis and asymptomatic bacteriuria progress to APN [1,6]. Factors that disrupt urinary flow such as vesicoureteral reflux, congenital urinary tract anomalies, altered bladder function, pregnancy, renal calculi, or mechanical obstruction increase the risk of developing APN [1,7,8].

In the majority of patients, uncomplicated APN is diagnosed clinically and is responsive to treatment with appropriate antibiotics [1]. In patients who are high risk or when treatment is delayed, microabscesses may coalesce to form an acute renal abscess. The renal parenchymal abscess can at times rupture into the perinephric space and lead to development of a perirenal abscess. In other cases, the infection may be confined to an obstructed collecting system causing pyonephrosis, or accumulation of purulent material in the upper urinary collecting system, that often requires decompression for treatment to be successful.

Some patients are at high risk for developing complications from APN. High-risk patients include those with a prior history of pyelonephritis, a lack of response to therapy for lower UTI or for APN, diabetes, anatomic or congenital abnormalities of the urinary system, infections by treatment-

resistant organisms, nosocomial infection, urolithiasis, renal obstruction, prior renal surgery, advanced age, and pregnancy; renal transplant recipients; and immunosuppressed or immunocompromised patients [1,8-10]. Pregnant patients and patients with renal transplants on immunosuppression are at elevated risk of severe complications. Imaging studies are often requested to aid with the diagnosis, identify precipitating factors, and differentiate lower UTI from renal parenchymal involvement, particularly in high-risk individuals. See the ACR Appropriateness Criteria<sup>®</sup> topics on "[Acute Onset Flank Pain-Suspicion of Stone Disease \(Urolithiasis\)](#)" [11], "[Hematuria](#)" [12], and "[Recurrent Lower Urinary Tract Infections in Females](#)" [13] for additional information.

### **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 the 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 evaluation of the upper and lower urinary tracts and without both the precontrast and excretory phases.

MR urography (MRU) is also tailored to improve imaging of the urinary system. Unenhanced MRU relies upon heavily T2-weighted imaging of the intrinsic high signal intensity from urine for the evaluation of the urinary tract. IV contrast is administered to provide additional information regarding obstruction, urothelial thickening, focal lesions, and stones. A contrast-enhanced T1-weighted series should include corticomedullary, nephrographic, and excretory phase. 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 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.

### **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 wherein each procedure provides unique clinical information to effectively manage the patient's care).

## **Discussion of Procedures by Variant**

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

### **A. CT Abdomen and Pelvis**

CT of the abdomen and pelvis is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [1,10,14,15]. CT imaging may be useful if symptoms persist for 72 hours [8,10,14,16]. Nearly 95% of patients with uncomplicated pyelonephritis become afebrile within 48 hours after appropriate antibiotic therapy, and nearly 100% become afebrile within 72 hours [8,14].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

### **B. CT Abdomen**

CT of the abdomen is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [1,10,14,15].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

### **C. CTU**

CTU is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [1,10,14,15].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

### **D. DMSA Renal Scan**

Tc-99m-labeled dimercaptosuccinic acid (DMSA) renal scintigraphy is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [15].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal**

**obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **E. Fluoroscopy Antegrade Pyelography**

Antegrade pyelography is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [15].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **F. Fluoroscopy Voiding Cystourethrography**

Fluoroscopy voiding cystourethrography (VCUG) is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [15].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **G. MRI Abdomen and Pelvis**

MRI of the abdomen and pelvis is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [15].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **H. MRI Abdomen**

MRI of the abdomen is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [15].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **I. MRU**

MRU of the abdomen and pelvis is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [15].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **J. Radiography Abdomen and Pelvis**

Radiography of the abdomen and pelvis (KUB) is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [15].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to**

**therapy, or pregnancy). Initial imaging.**

#### **K. Radiography Intravenous Urography**

Intravenous urography (IVU) is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [15].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **L. US Abdomen**

Ultrasound (US) of the abdomen is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [15]. In addition, US had inferior accuracy for detection of APN compared with CT [10,17].

**Variant 1: Suspected acute pyelonephritis. First-time presentation. Uncomplicated patient (eg, no history of pyelonephritis, diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **M. US Color Doppler Kidneys and Bladder Retroperitoneal**

US color doppler of the kidneys, bladder, and retroperitoneum is not beneficial in the initial imaging evaluation for the first-time presentation of suspected APN in an uncomplicated patient [15].

**Variant 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

The goal of imaging in a complicated patient with suspected APN is to identify the presence or absence of APN and identify associated complications. Patients with a history of renal calculi are separately discussed in variant 3.

**Variant 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **A. CT Abdomen and Pelvis**

There is widespread agreement that CT of the abdomen and pelvis with IV contrast is a useful study to diagnose APN in a complicated patient without a prior history of stone disease [1,8,14-21]. CT imaging should include the pelvis for multiple reasons. For example, unsuspected urolithiasis can be in the distal ureters or urinary bladder, congenital abnormalities of the distal ureters and abnormal insertion sites can be identified, and abnormalities of the urinary bladder can be detected, among other potential sources of APN.

Contrast-enhanced CT can be used to detect signs of APN including focal or multifocal decreased parenchymal enhancement, complications of APN including a renal or perirenal abscess or emphysematous pyelonephritis, and underlying problems including hydronephrosis, obstructing stones, or congenital abnormalities [1,8,14,17-19]. In a retrospective study of patients with suspected APN that underwent both unenhanced and contrast-enhanced CT (n = 183), contrast-enhanced CT detected parenchymal involvement in 62.5% of patients, whereas unenhanced CT detected parenchymal involvement in only 1.4% of cases, and 4.6% of patients had renal abscesses



that were missed on unenhanced CT and only detected on contrast-enhanced CT [19]. Furthermore, unenhanced CT missed the diagnosis of acute extrarenal conditions including cholecystitis (n = 1), liver abscess (n = 1), and appendicitis (n = 1), which were all subsequently diagnosed with contrast-enhanced CT [19].

In the absence of a history of renal stones, the benefit of performing unenhanced CT in combination with contrast-enhanced CT is negligible in a complicated patient with suspected APN. In a small retrospective study of adult patients with clinical and laboratory suspicion of APN who all underwent triphasic abdominal CT (n = 100), the accuracy of the nephrographic phase among 2 readers for diagnosis of APN was 90% to 92% and for diagnosis of urolithiasis was 96% to 99% [22]. There was no significant difference in the accuracy of the triphasic abdominal CT relative to the nephrographic phase only [22].

In a prospective nonrandomized data collection study of patients with a final diagnosis of APN (n = 827), the detection rate of APN was 84.4% (445/527) by abdominal CT and only 40% (72/180) by abdominal US [10]. Although the detection rate of urolithiasis and hydronephrosis were similar by abdominal CT and abdominal US, the rate of detection of renal abscess was 4.0% (21/527) by abdominal CT and only 1.1% (2/180) by US [10].

US, CT, and MRI can show evidence of chronic pyelonephritis, including renal scarring, atrophy and cortical thinning, hypertrophy of residual normal tissue, and renal asymmetry [1,8,14,15,17,19,20]. Advantages of abdominal CT and US over abdominal MRI may include superior detection of urolithiasis, and CT may be superior to US and MRI in detection of gas in emphysematous pyelonephritis [1,14,15,18].

Contrast-enhanced CT of the abdomen and pelvis is supported in high-risk or complicated patients if initial treatment is unresponsive or symptoms worsen [1,2,8,10,15,17-19]. In general, contrast-enhanced CT of the abdomen and pelvis should be delayed 72 hours after initiation of therapy [1,8,14-21].

**Variante 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **B. CT Abdomen**

CT of the abdomen with IV contrast has high accuracy for the diagnosis of APN in a complicated patient but does not allow for a comprehensive assessment of the entire genitourinary tract [1,8,14-21]. CT imaging should include the pelvis to detect potential pelvic abnormalities including urolithiasis in the distal ureters or urinary bladder, congenital abnormalities of the distal ureters and abnormal insertion sites, and abnormalities of the urinary bladder, among other potential sources of APN.

**Variante 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **C. CTU**

There is insufficient evidence to support the use of CTU for detection of suspected APN in the complicated patient. There is variability in CTU imaging technique. The added benefit of an excretory phase from any CTU image acquisition protocol is likely negligible with respect to

detection and characterization of APN in a complicated patient.

**VARIANT 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **D. DMSA Renal Scan**

According to the literature, renal scintigraphy, specifically Tc-99m DMSA scan, is not beneficial for the diagnosis of APN in adults. In contrast, renal scintigraphy is useful in the pediatric population where there is difficulty in differentiating lower UTI from APN [23]. However, differentiation of lower UTI from APN is less problematic in adults, and pediatric vesicoureteral reflux often resolves in adulthood. Furthermore, in a small prospective study of adult patients with UTIs who underwent both contrast-enhanced CT and DMSA (n = 36), CT had higher accuracy in diagnosis of APN [24].

**VARIANT 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **E. Fluoroscopy Antegrade Pyelography**

Antegrade pyelography is not beneficial in the imaging evaluation for suspected APN in a complicated adult patient [15].

**VARIANT 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **F. Fluoroscopy Voiding Cystourethrography**

VCUG is commonly used to identify vesicoureteral reflux but is not beneficial in the acute setting. VCUG is usually performed after resolution of acute symptoms to assess for an underlying anatomic or congenital cause, particularly in children with recurrent febrile UTIs [25]. Adult women with predisposing factors suspicious for vesicoureteral reflux may also benefit from VCUG [26]. However, VCUG is likely of limited benefit in the acute setting.

**VARIANT 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **G. MRI Abdomen and Pelvis**

MRI of the abdomen without or with IV contrast may be useful for detecting and characterizing congenital anomalies of the kidneys, and imaging of the pelvis could improve detection of congenital abnormalities of the distal ureters and abnormalities of the urinary bladder. In general, MRI of the pelvis is usually not combined with MRI of the abdomen unless an MRU is being performed. Diffusion-weighted imaging (DWI) [20] and contrast-enhanced MRI have similar benefits in detecting renal abnormalities [27]. Studies in adults have shown that DWI can be useful in the diagnosis of uncomplicated pyelonephritis [28-30]. APN, renal abscesses, and pyonephrosis have lower apparent diffusion coefficient (ADC) values than normal renal cortical parenchyma [28]. As such, DWI and ADC provide a viable alternative to contrast-enhanced MRI or CT [30].

Disadvantages of MRI includes relatively poor accuracy for detection of urolithiasis and relatively reduced ability to detect gas in emphysematous pyelonephritis [31,32]. Similar to CT, MRI does not provide benefit early in uncomplicated cases [8,14].

**VARIANT 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis,**

**diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **H. MRI Abdomen**

MRI of the abdomen has high accuracy for the diagnosis of APN in a complicated patient but does not allow for a comprehensive assessment of the entire genitourinary tract. Failure to include the pelvis could lead to a missed opportunity to detect urolithiasis in the distal ureters or urinary bladder, congenital abnormalities of the distal ureters and abnormal ureteral insertion sites, and abnormalities of the urinary bladder, among other potential sources of APN.

**Variante 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **I. MRU**

The excretory phase of MRU does not confer additional benefit with respect to detection and characterization of APN in a complicated patient. Studies comparing MRU with DMSA renal scintigraphy for the detection of pyelonephritis and renal scarring have shown that MRU without and with IV contrast is at least equivalent or superior to DMSA for this specific purpose [33-35]. No studies of MRU without IV contrast were identified in the literature.

**Variante 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **J. Radiography Abdomen and Pelvis**

Radiography of the abdomen and pelvis (KUB) is not beneficial in the imaging evaluation for suspected APN in a complicated adult patient [15].

**Variante 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **K. Radiography Intravenous Urography**

IVU is not beneficial in the imaging evaluation for suspected APN in a complicated adult patient [15].

**Variante 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **L. US Abdomen**

Although US of the abdomen has similar accuracy to CT for detection of urolithiasis and hydronephrosis, the main disadvantages of US compared with CT are a lower rate of detection of APN and renal abscess, but it can be performed portably and without IV contrast [10,36-38]. Of note, the sensitivity for detection of acute complicated pyelonephritis and for detection of a renal abscess is higher with contrast-enhanced US relative to unenhanced US [37,38]. In one small retrospective study of adults with APN (n = 100), the accuracy of contrast-enhanced US for detection of APN approached that of contrast-enhanced CT [39].

**Variante 2: Suspected acute pyelonephritis. Complicated patient (eg, recurrent pyelonephritis, diabetes, immune compromise, advanced age, vesicoureteral reflux, or lack of response to initial therapy). Initial imaging.**

#### **M. US Color Doppler Kidneys and Bladder Retroperitoneal**

US including color Doppler has been shown to increase sensitivity for detection of APN beyond grayscale US [40]. US with power Doppler has been shown to have sensitivities and specificities that approach 90% in children with APN [41,42] and may have similar results in adults.

Although US has similar accuracy to CT for detection of urolithiasis and hydronephrosis, the main disadvantages of US compared with CT are a lower rate of detection of APN and renal abscess [10,36-38]. Of note, the sensitivity for detection of acute complicated pyelonephritis and for detection of a renal abscess is higher with contrast-enhanced US relative to unenhanced US [37,38].

**Variant 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

**Variant 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

**A. CT Abdomen and Pelvis**

Renal stones or renal obstruction can be a source of APN [1,8,11,15,18,19]. CT of the abdomen and pelvis is highly sensitive for detection of stones and hydronephrosis [8,11]. Furthermore, CT is a useful imaging study to diagnose APN if symptoms persist or worsen after 72 hours have passed [1,8,14-21]. CT imaging should include the pelvis to identify stones in the distal ureters or urinary bladder, congenital abnormalities of the distal ureters, and abnormalities of the urinary bladder, among other potential sources of APN.

Both unenhanced and contrast-enhanced CT are able to detect urolithiasis, perinephric fluid, renal swelling, and hydronephrosis [1,8,14,17-19]. However, contrast-enhanced CT has been shown to improve detection of APN parenchymal changes, a renal abscess, and extrarenal acute conditions that may clinical present as suspicious for APN [19]. Of note, unenhanced CT has higher sensitivity than contrast-enhanced CT for detection of small renal calculi.

In a prospective nonrandomized data collection study of patients with a final diagnosis of APN (n = 827), the detection rate of APN was 84.4% (445/527) by abdominal CT and only 40% (72/180) by abdominal US [10]. Although the detection rate of urolithiasis and hydronephrosis were similar by abdominal CT and abdominal US, the rate of detection of renal abscess was 4.0% (21/527) by abdominal CT and only 1.1% (2/180) by US [10].

CT and US have similar detection rates for renal stones and hydronephrosis. Advantages of abdominal CT and US over abdominal MRI may include superior detection of small urothelial stones [1,14,15,18].

In a small retrospective study of adult patients with clinical and laboratory suspicion of APN who all underwent triphasic abdominal CT (n = 100), the accuracy of the nephrographic phase among 2 readers for diagnosis of APN was 90% to 92% and for diagnosis of urolithiasis was 96% to 99% [22]. There was no significant difference in the accuracy of the triphasic abdominal CT relative to nephrographic phase alone [22]. Thereby, detection of urothelial stones is similar with unenhanced and contrast-enhanced CT.

**Variant 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

**B. CT Abdomen**

CT of the abdomen without IV contrast has high accuracy for detection of renal stones, and CT of the abdomen with IV contrast has high accuracy for the diagnosis of APN. However, CT of the abdomen alone does not allow for a comprehensive assessment of the entire genitourinary tract [1,8,14-21]. CT imaging should include the pelvis to detect potential pelvic abnormalities including urolithiasis in the distal ureters or urinary bladder, congenital abnormalities of the distal ureters and abnormal insertion sites, and abnormalities of the urinary bladder, among other potential sources of APN.

**Variante 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

#### **C. CTU**

There is insufficient evidence to support the use of CTU for detection of suspected APN in the complicated patient. There is variability in the CTU imaging technique. The added benefit of an excretory phase from any CTU image acquisition protocol is likely negligible with respect to detection and characterization of APN in a complicated patient.

**Variante 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

#### **D. DMSA Renal Scan**

CT may have higher accuracy than DMSA renal scintigraphy for detection of APN and certainly has higher accuracy for detection of stones, which cannot be directly visualized by renal scintigraphy [24].

**Variante 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

#### **E. Fluoroscopy Antegrade Pyelography**

Antegrade pyelography is not beneficial in the imaging evaluation for suspected APN in a patient with a history of renal stones or renal obstruction [15].

**Variante 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

#### **F. Fluoroscopy Voiding Cystourethrography**

VCUG is not beneficial in the imaging evaluation for suspected APN in a patient with a history of renal stones or renal obstruction [15].

**Variante 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

#### **G. MRI Abdomen and Pelvis**

MRI of the abdomen and pelvis can be useful for detecting APN, scarring, congenital anomalies of the kidneys, renal abscesses, hydronephrosis, and pyonephrosis [28-30], and imaging of the pelvis could improve detection of stones in the distal ureters or urinary bladder, congenital abnormalities of the distal ureters, and abnormalities of the urinary bladder, among other potential sources of APN. However, MRI has poor accuracy for the detection of small urothelial calculi [31,32]. Other disadvantages of MRI include its relatively reduced ability to detect gas in emphysematous pyelonephritis [31,32]. Similar to CT, MRI is not beneficial early in uncomplicated cases [8,14].

**Variante 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

#### **H. MRI Abdomen**

MRI of the abdomen has high accuracy for the diagnosis of APN in a complicated patient but does not allow for a comprehensive assessment of the entire genitourinary tract. Failure to include the pelvis could lead to a missed opportunity to detect urolithiasis in the distal ureters or urinary bladder, congenital abnormalities of the distal ureters and abnormal ureteral insertion sites, and abnormalities of the urinary bladder, among other potential sources of APN.

MRI has poor accuracy for the detection of small urothelial calculi. Another disadvantage of MRI includes its relatively reduced ability to detect gas in emphysematous pyelonephritis [31,32].

**Variant 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

**I. MRU**

The excretory phase of MRU does not confer additional benefit with respect to detection and characterization of APN in a complicated patient. Furthermore, MRU has poor accuracy for the detection of small urothelial calculi [31,32]. In a small prospective study comparing CTU with MRU in adult patients referred from the emergency department for evaluation of renal colic or hematuria (n = 70), all cases of urinary stones were detected by CTU (100%) versus 79% of cases detected by MRU [43]. Another disadvantage of MRU includes its relatively reduced ability to detect gas in emphysematous pyelonephritis [31,32].

**Variant 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

**J. Radiography Abdomen and Pelvis**

Radiography of the abdomen and pelvis (KUB) has limited utility in the imaging evaluation for suspected APN in a patient with a history of renal stones or renal obstruction [15]. Although radiography of the abdomen and pelvis could detect large calculi, it cannot detect APN.

**Variant 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

**K. Radiography Intravenous Urography**

IVU is not beneficial in the imaging evaluation for suspected APN in a patient with a history of renal stones or renal obstruction [15].

**Variant 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

**L. US Abdomen**

US of the kidneys has nearly 100% sensitivity for detection of large stones (>5 mm) and hydronephrosis, although the accuracy for detection of small stones (<3 mm) is poor [44,45].

Some disadvantages of US compared with CT are a lower rate of detection of APN and renal abscess [10,36-38]. Of note, the sensitivity for detection of acute complicated pyelonephritis and for detection of a renal abscess is higher with contrast-enhanced US relative to unenhanced US [37,38]. In one small retrospective study of adults with APN (n = 100), the accuracy of contrast-enhanced US for detection of APN approached that of contrast-enhanced CT [39].

**Variant 3: Suspected acute pyelonephritis. History of renal stones or renal obstruction. Initial imaging.**

**M. US Color Doppler Kidneys and Bladder Retroperitoneal**

US of the kidneys has nearly 100% sensitivity for detection of large stones (>5 mm) and

hydronephrosis, although the accuracy for detection of small stones (<3 mm) is poor [44,45]. Use of color Doppler has been shown to increase sensitivity for detection of APN in adults and children [40-42]. Inclusion of the bladder could identify other abnormalities contributing to APN. A disadvantage of US compared with CT is a lower rate of detection of APN and renal abscess [10,36-38].

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **A. CT Abdomen and Pelvis**

There is no current literature specific to the use of CT of the abdomen and pelvis in the evaluation of suspected APN in pregnant patients. CT imaging of the abdomen and pelvis is not supported as the initial imaging in pregnant patients. The main disadvantage of using CT of the abdomen and pelvis in a pregnant patient is the risk of ionizing radiation to the embryo or fetus and the mother, particularly for the pelvic portion of the examination [46].

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **B. CT Abdomen**

There is no current literature to support the use of CT of the abdomen in the evaluation of suspected APN in pregnant patients. CT imaging of the abdomen does not allow for detection of pelvic abnormalities including urolithiasis in the distal ureters or urinary bladder, congenital abnormalities of the distal ureters and abnormal insertion sites, and abnormalities of the urinary bladder, among other potential sources of APN.

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **C. CTU**

There is no current literature to support the use of CTU in the evaluation of suspected APN in pregnant patients. There is variability in CTU imaging technique. The added benefit of an excretory phase from any CTU image acquisition protocol is likely negligible with respect to the detection and characterization of APN in a pregnant patient. A CTU protocol that does not include unenhanced imaging and that uses a split bolus to achieve a mixed nephrographic and excretory phase could mask the presence of urolithiasis.

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **D. DMSA Renal Scan**

DMSA renal scintigraphy is not beneficial in the imaging evaluation for suspected APN in a pregnant patient [15].

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior**

**renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **E. Fluoroscopy Antegrade Pyelography**

Antegrade pyelography is not beneficial in the imaging evaluation for suspected APN in a pregnant patient [15].

**Variante 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **F. Fluoroscopy Voiding Cystourethrography**

VCUG is not beneficial in the imaging evaluation for suspected APN in a pregnant patient [15].

**Variante 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **G. MRI Abdomen and Pelvis**

There is no current literature specific to the use of MRI of the abdomen and pelvis in the evaluation of suspected APN in pregnant patients. MRI of the abdomen and pelvis is generally safe in pregnant patients and may be useful in certain situations. MRI does not expose the embryo, or fetus, or pregnant mother to ionizing radiation and can be useful for detecting APN, scarring, congenital anomalies of the kidneys, renal abscesses, hydronephrosis, and pyonephrosis [28-30]. Although there are no known adverse effects to human fetuses and no known cases of nephrogenic systemic fibrosis linked to the use of clinical doses of gadolinium-based contrast agents (GBCAs) in pregnant patients, GBCAs should only be used if the indication is considered critical and the potential benefits justify the potential unknown risk to the fetus [47].

MRI of the abdomen can be useful for detecting APN, scarring, congenital anomalies of the kidneys, renal abscesses, hydronephrosis, and pyonephrosis [28-30]. DWI [20] and contrast-enhanced MRI have similar benefits in detecting renal abnormalities [27]. Studies in adults have shown that DWI can be useful in the diagnosis of pyelonephritis [28-30]. APN, renal abscesses, and pyonephrosis have lower ADC values than normal renal cortical parenchyma [28]. Inclusion of the pelvis could improve detection of abnormalities of the lower urinary tract.

MRI may allow for a limited evaluation of the embryo or fetus. However, traditional MRI examinations do not provide a comprehensive assessment of the urinary collecting systems [8,31,32]. The main disadvantages of MRI are poor accuracy for the detection of small urothelial calculi and reduced accuracy for detection of emphysematous pyelonephritis, [31,32].

**Variante 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **H. MRI Abdomen**

There is no current literature specific to the use of MRI of the abdomen in the evaluation of suspected APN in pregnant patients. MRI of the abdomen does not allow for detection of pelvic abnormalities including urolithiasis in the distal ureters or urinary bladder, congenital abnormalities of the distal ureters and abnormal insertion sites, and abnormalities of the urinary bladder, among other potential sources of APN. MRI of the abdomen is generally safe in pregnant patients and may be useful in certain situations [28-30]. Although there are no known adverse effects to human fetuses and no known cases of nephrogenic systemic fibrosis linked to the use of clinical doses of



GBCAs in pregnant patients, GBCAs should only be used if the indication is considered critical and the potential benefits justify the potential unknown risk to the fetus [47].

MRI of the abdomen may allow for a limited evaluation of the embryo or fetus, although most fetuses would not be included in the field of view. The main disadvantages of MRI are poor accuracy for the detection of small urothelial calculi and reduced accuracy for detection of emphysematous pyelonephritis [31,32].

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **I. MRU**

There is no current literature specific to the use of MRU without IV contrast in the evaluation of suspected APN in pregnant patients. The excretory phase of MRU does not confer additional benefit with respect to detection and characterization of APN in a pregnant patient.

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **J. Radiography Abdomen and Pelvis**

Radiography of the abdomen and pelvis is not beneficial in the imaging evaluation for suspected APN in a pregnant patient [15].

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **K. Radiography Intravenous Urography**

IVU is not beneficial in the imaging evaluation for suspected APN in a pregnant patient [15].

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **L. US Abdomen**

There is no current literature specific to the use of US of the abdomen in the evaluation of suspected APN in pregnant patients. Pregnancy increases the risk of complications from APN, although poor obstetrical outcomes are rare [48]. US of the abdomen may be used to detect complications of APN. US of the abdomen is safe in pregnancy and is rapid and portable and does not require the use of contrast material [8]. US is often used as a screening examination in pregnancy, is sensitive and specific test for diagnosing hydronephrosis, and does not expose the patient or fetus to ionizing radiation [49,50].

Physiologic hydronephrosis of pregnancy occurs in >80% of pregnant patients in the second and third trimester; therefore, hydronephrosis alone is not a reliable sign of APN in pregnant patients [51]. Furthermore, US has a low detection rate of APN and renal abscess [10,36-38].

**Variant 4: Suspected acute pyelonephritis. Pregnant female with no other complications (eg, no history of diabetes, immune compromise, history of stones or renal obstruction, prior renal surgery, vesicoureteral reflux, or lack of response to therapy). Initial imaging.**

#### **M. US Color Doppler Kidneys and Bladder Retroperitoneal**

There is no current literature specific to the use of US color Doppler of the kidneys, bladder, and retroperitoneum in the evaluation of suspected APN in pregnant patients. US of the kidney, ureters, and bladder is safe in pregnancy, is rapid and portable, and does not require the use of contrast material [8]. US is often used as a screening examination in pregnancy, is sensitive and specific test for diagnosing hydronephrosis, and does not expose the patient or fetus to ionizing radiation [49,50]. Use of color Doppler has been shown to increase sensitivity for detection of APN compared to US with grayscale imaging [40-42].

Physiologic hydronephrosis of pregnancy occurs in >80% of pregnant patients in the second and third trimester; therefore, hydronephrosis alone is not a reliable sign of APN in pregnant patients [51]. Furthermore, US has a lower detection rate of APN and renal abscess than CT [10,36-38].

**Variant 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

Some local practice patterns do not routinely give IV contrast agents to patients with renal transplants. For this variant, we assumed there are no contraindications to IV contrast agents.

**Variant 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **A. CT Abdomen and Pelvis**

There is no current literature specific to the use of CT of the abdomen and pelvis in the evaluation of suspected APN in a patient with a pelvic renal transplant and native kidneys in situ. CT of the abdomen and pelvis would include imaging of the native and transplant kidneys, and CT with IV contrast is highly accurate for the diagnose APN in a complicated patient, particularly if symptoms persist or worsen after 72 hours have passed [1,8,14-21].

Both unenhanced and contrast-enhanced CT are able to detect urolithiasis, perinephric fluid, renal swelling, and hydronephrosis [1,8,14,17-19]. Contrast-enhanced CT has been shown to improve detection of APN parenchymal changes, a renal abscess, and extrarenal acute conditions that may clinically present as suspicious for APN. CT imaging of the pelvis can detect potential pelvic abnormalities including urolithiasis in the distal ureters or urinary bladder, congenital abnormalities of the distal ureters and abnormal insertion sites, and abnormalities of the urinary bladder, among other potential sources of APN. Of note, unenhanced CT has higher sensitivity than contrast-enhanced CT for detection of small renal calculi.

**Variant 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **B. CT Abdomen**

There is no current literature to support the use of CT of the abdomen in the evaluation of suspected APN in a patient with a pelvic renal transplant and native kidneys in situ. APN of a renal allograft is more common than APN of the native kidneys, and renal transplant recipients are at high risk for complications from a variety of factors, including immunosuppression [52]. CT of the

abdomen would not include complete imaging of the pelvic transplant kidney(s), which might miss important pathology in the transplant kidney [1,8,14-21].

**Variante 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

### **C. CTU**

There is limited information on the benefit of CTU for detection of suspected APN in a patient with a pelvic renal transplant and native kidneys in situ. The added benefit of an excretory phase from any CTU image acquisition protocol is likely negligible with respect to detection and characterization of APN in this patient cohort.

**Variante 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

### **D. DMSA Renal Scan**

DMSA renal scintigraphy is not beneficial in the imaging evaluation for suspected APN in a patient with a pelvic renal transplant and native kidneys in situ [15].

**Variante 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

### **E. Fluoroscopy Antegrade Pyelography**

Antegrade pyelography is not beneficial in the imaging evaluation for suspected APN in a patient with a pelvic renal transplant and native kidneys in situ [15].

**Variante 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

### **F. Fluoroscopy Voiding Cystourethrography**

VCUG is not beneficial in the imaging evaluation for suspected APN in a patient with a pelvic renal transplant and native kidneys in situ [15].

**Variante 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

### **G. MRI Abdomen and Pelvis**

There is limited literature on the use of MRI of the abdomen and pelvis in the evaluation of suspected APN in a patient with a pelvic renal transplant and native kidneys in situ. APN is rare in native kidneys. However, APN of a renal allograft is more common, and renal transplant recipients are at high risk for complications from a variety of factors, including immunosuppression [52].

In a prospective study of renal transplant recipients with suspected APN (n = 56), contrast-enhanced MRI was positive in 66% (37/56) of patients [53]. In a small retrospective study of 24

kidney transplant recipients who underwent MRI without IV contrast and had clinical suspicion of APN, 92% (22/24) of patients had positive findings on MRI, specifically on DWI and ADC images [54].

Studies in adult patients without renal transplants have shown that DWI can be useful in the diagnosis of uncomplicated pyelonephritis [28-30]. APN, renal abscesses, and pyonephrosis have lower ADC values than normal renal cortical parenchyma [28]. As such, DWI and ADC provide a viable alternative to contrast-enhanced MRI or CT [30].

The main disadvantages of MRI of the abdomen and pelvis are poor accuracy for the detection of small urothelial calculi and reduced accuracy for detection of emphysematous pyelonephritis, [31,32].

**Variant 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **H. MRI Abdomen**

There is limited literature on the use of MRI of the abdomen in the evaluation of suspected APN in a patient with a pelvic renal transplant and native kidneys in situ. APN is rare in native kidneys, and abdominal imaging would not include complete imaging of the pelvic transplant kidney(s), which would likely miss important pathology in the transplant kidney [1,8,14-21].

**Variant 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **I. MRI Pelvis**

There is limited literature on the use of MRI of the pelvis in the evaluation of suspected APN in a patient with a pelvic renal transplant and native kidneys in situ. Pelvic MRI alone would not include evaluation of the native kidneys. MRI of the abdomen and pelvis would be more comprehensive for identification of the source of the APN.

**Variant 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **J. MRU**

There is no current literature specific to the use of MRU in the evaluation of suspected APN in patients with a pelvic renal transplant and native kidneys in situ. The excretory phase of MRU does not confer additional benefit with respect to detection and characterization of APN in a pregnant patient.

**Variant 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **K. Radiography Abdomen and Pelvis**

Radiography of the abdomen and pelvis is not beneficial in the imaging evaluation for suspected

APN in a patient with a pelvic renal transplant and native kidneys in situ [15].

**Variants 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **L. Radiography Intravenous Urography**

IVU is not beneficial in the imaging evaluation for suspected APN in a patient with a pelvic renal transplant and native kidneys in situ [15].

**Variants 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **M. US Abdomen**

APN is rare in native kidneys. Because an US of the abdomen would not include complete imaging of the pelvic transplant kidney(s), the examination is not likely to diagnose APN [1,8,14-21].

**Variants 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **N. US Color Doppler Kidneys and Bladder Retroperitoneal**

APN is most commonly an issue with the transplant kidney. Because US Doppler of the kidneys, bladder, and retroperitoneum does not include imaging of the pelvic transplant kidney(s), the examination is not likely to diagnose APN.

**Variants 5: Suspected acute pyelonephritis. History of pelvic renal transplant with native kidneys in situ and no other complications (eg, no history of pyelonephritis, diabetes, history of stones or renal obstruction, prior renal surgery, advanced age, vesicoureteral reflux, lack of response to therapy, or pregnancy). Initial imaging.**

#### **O. US Duplex Doppler Kidney Transplant**

Renal transplant US includes grayscale and color doppler imaging and is commonly used to assess transplant dysfunction. According to the American Institute of Ultrasound in Medicine, renal transplant US is the recommended imaging examination to evaluate for suspected APN of a renal transplant. Renal transplant US has high resolution and high sensitivity for detection of renal transplant hydronephrosis, calculi, vascular abnormalities, and a renal or perirenal abscess.

In a prospective study of renal transplant recipients with suspected APN (n = 56) using contrast-enhanced MRI served as the reference standard that was positive in 66% (37/56), the contrast-enhanced US was positive in 63% (35/56) of patients, with a reported sensitivity of 95%, a specificity of 100%, and a diagnostic accuracy of 96% [53].

### **Summary of Recommendations**

- **Variants 1:** Imaging is usually not appropriate for the first-time presentation of suspected APN in an uncomplicated patient.
- **Variants 2:** CT abdomen and pelvis with IV contrast is usually appropriate for the initial

imaging of complicated patients with suspected APN. Although the panel did not agree on recommending CT abdomen with IV contrast or CT abdomen and pelvis without and with IV contrast because there is insufficient medical literature to conclude whether these patients would benefit from the procedures, their use may be appropriate.

- **Variation 3:** CT abdomen and pelvis with IV contrast or CT abdomen and pelvis without and with IV contrast is usually appropriate for the initial imaging of patients with a history of renal stones or renal obstruction with suspected APN. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care). Although the panel did not agree on recommending CT abdomen without and with IV contrast because there is insufficient medical literature to conclude whether these patients would benefit from the procedure, its use may be appropriate.
- **Variation 4:** US color Doppler kidneys and bladder retroperitoneal or MRI abdomen and pelvis without IV contrast or MRI abdomen without IV contrast or MRU without IV contrast may be appropriate for the initial imaging of pregnant patients with no other complications. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care). Although the panel did not agree on recommending US abdomen because there is insufficient medical literature to conclude whether these patients would benefit from the procedure, its use may be appropriate.
- **Variation 5:** US duplex Doppler kidney transplant or CT abdomen and pelvis with IV contrast is usually appropriate for the initial imaging of patients with a history of pelvic renal transplant with native kidneys in situ and no other complications with suspected APN. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

## 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)
- ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation
- ACR-ACOG-AIUM-SMFM-SRU Practice Parameter for the Performance of Standard Diagnostic Obstetrical Ultrasound
- ACR Manual on Contrast Media




### 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 [58].

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 (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."		

## References

1. Johnson JR, Russo TA. Acute Pyelonephritis in Adults. *N Engl J Med* 2018;378:48-59.
2. Czaja CA, Scholes D, Hooton TM, Stamm WE. Population-based epidemiologic analysis of acute pyelonephritis. *Clin Infect Dis* 2007;45:273-80.
3. Stamm WE, Hooton TM, Johnson JR, et al. Urinary tract infections: from pathogenesis to treatment. *J Infect Dis* 1989;159:400-6.
4. Talan DA, Takhar SS, Krishnadasan A, et al. Fluoroquinolone-Resistant and Extended-Spectrum beta-Lactamase-Producing *Escherichia coli* Infections in Patients with Pyelonephritis, United States(1). *Emerg Infect Dis* 2016;22:1594-603.
5. Scholes D, Hooton TM, Roberts PL, Gupta K, Stapleton AE, Stamm WE. Risk factors associated with acute pyelonephritis in healthy women. *Ann Intern Med* 2005;142:20-7.
6. Ikaheimo R, Siitonen A, Heiskanen T, et al. Recurrence of urinary tract infection in a primary care setting: analysis of a 1-year follow-up of 179 women. *Clin Infect Dis* 1996;22:91-9.
7. Godaly G, Ambite I, Svanborg C. Innate immunity and genetic determinants of urinary tract infection susceptibility. *Curr Opin Infect Dis* 2015;28:88-96.
8. Nikolaidis P, Dogra VS, Goldfarb S, et al. ACR Appropriateness Criteria R Acute Pyelonephritis. *Journal of the American College of Radiology*. 15(11S):S232-S239, 2018 Nov.
9. Velasco M, Martinez JA, Moreno-Martinez A, et al. Blood cultures for women with uncomplicated acute pyelonephritis: are they necessary? *Clin Infect Dis* 2003;37:1127-30.
10. Kim Y, Seo MR, Kim SJ, et al. Usefulness of Blood Cultures and Radiologic Imaging Studies in the Management of Patients with Community-Acquired Acute Pyelonephritis. *Infect Chemother* 2017;49:22-30.
11. American College of Radiology. ACR Appropriateness Criteria®: Acute Onset Flank Pain-Suspicion of Stone Disease (Urolithiasis). Available at: <https://acsearch.acr.org/docs/69362/Narrative/>.
12. Wolfman DJ, Marko J, Nikolaidis P, et al. ACR Appropriateness Criteria R Hematuria. *Journal of the American College of Radiology*. 17(5S):S138-S147, 2020 May. *J. Am. Coll. Radiol.* 17(5S):S138-S147, 2020 May.
13. Venkatesan AM, Oto A, Allen BC, et al. ACR Appropriateness Criteria R Recurrent Lower Urinary Tract Infections in Females. *Journal of the American College of Radiology*. 17(11S):S487-S496, 2020 Nov. *J. Am. Coll. Radiol.* 17(11S):S487-S496, 2020 Nov.
14. Soulen MC, Fishman EK, Goldman SM, Gatewood OM. Bacterial renal infection: role of CT. *Radiology*. 1989; 171(3):703-707.



15. Craig WD, Wagner BJ, Travis MD. Pyelonephritis: radiologic-pathologic review. *Radiographics*. 2008;28(1):255-277; quiz 327-258.
16. Abraham G, Reddy YN, George G. Diagnosis of acute pyelonephritis with recent trends in management. *Nephrol Dial Transplant* 2012;27:3391-4.
17. Pierce C, Keniston A, Albert RK. Imaging in Acute Pyelonephritis: Utilization, Findings, and Effect on Management. *Southern Medical Journal*. 112(2):118-124, 2019 02. *South Med J*. 112(2):118-124, 2019 02.
18. Enikeev DV, Glybochko P, Alyaev Y, Enikeev M, Rapoport L. Imaging technologies in the diagnosis and treatment of acute pyelonephritis. *Urologia (Treviso)*. 84(3):179-184, 2017 Aug 01. *Urologia*. 84(3):179-184, 2017 Aug 01.
19. Lee A, Kim HC, Hwang SI, et al. Clinical Usefulness of Unenhanced Computed Tomography in Patients with Acute Pyelonephritis. *Journal of Korean Medical Science*. 33(38):e236, 2018 Sep 17. *J Korean Med Sci*. 33(38):e236, 2018 Sep 17.
20. Bova JG, Potter JL, Arevalos E, Hopens T, Goldstein HM, Radwin HM. Renal and perirenal infection: the role of computerized tomography. *J Urol*. 1985; 133(3):375-378.
21. Dalla-Palma L, Pozzi-Mucelli F, Pozzi-Mucelli RS. Delayed CT findings in acute renal infection. *Clin Radiol*. 1995; 50(6):364-370.
22. Taniguchi LS, Torres US, Souza SM, Torres LR, D'Ippolito G. Are the unenhanced and excretory CT phases necessary for the evaluation of acute pyelonephritis?. *Acta Radiologica*. 58(5):634-640, 2017 May. *Acta Radiol*. 58(5):634-640, 2017 May.
23. Sfakianaki E, Sfakianakis GN, Georgiou M, Hsiao B. Renal scintigraphy in the acute care setting. *Semin Nucl Med*. 2013;43(2):114-128.
24. Sattari A, Kampouridis S, Damry N, et al. CT and 99mTc-DMSA scintigraphy in adult acute pyelonephritis: a comparative study. *J Comput Assist Tomogr*. 2000; 24(4):600-604.
25. Lee JH, Kim MK, Park SE. Is a routine voiding cystourethrogram necessary in children after the first febrile urinary tract infection? *Acta Paediatr*. 2012;101(3):e105-109.
26. Choi YD, Yang WJ, Do SH, Kim DS, Lee HY, Kim JH. Vesicoureteral reflux in adult women with uncomplicated acute pyelonephritis. *Urology*. 2005;66(1):55-58.
27. Vivier PH, Sallem A, Beurdeley M, et al. MRI and suspected acute pyelonephritis in children: comparison of diffusion-weighted imaging with gadolinium-enhanced T1-weighted imaging. *Eur Radiol*. 2014;24(1):19-25.
28. Rathod SB, Kumbhar SS, Nanivadekar A, Aman K. Role of diffusion-weighted MRI in acute pyelonephritis: a prospective study. *Acta Radiologica*. 56(2):244-9, 2015 Feb.
29. Faletti R, Cassinis MC, Fonio P, et al. Diffusion-weighted imaging and apparent diffusion coefficient values versus contrast-enhanced MR imaging in the identification and characterisation of acute pyelonephritis. *Eur Radiol* 2013;23:3501-8.
30. De Pascale A, Piccoli GB, Priola SM, et al. Diffusion-weighted magnetic resonance imaging: new perspectives in the diagnostic pathway of non-complicated acute pyelonephritis. *Eur Radiol*. 2013;23(11):3077-3086.
31. Chua ME, Ming JM, Farhat WA. Magnetic resonance urography in the pediatric population: a clinical perspective. [Review]. *Pediatric Radiology*. 46(6):791-5, 2016 May.

32. Leyendecker JR, Clingan MJ. Magnetic resonance urography update--are we there yet? *Semin Ultrasound CT MR* 2009;30:246-57.
33. Cerwinka WH, Grattan-Smith JD, Jones RA, et al. Comparison of magnetic resonance urography to dimercaptosuccinic acid scan for the identification of renal parenchyma defects in children with vesicoureteral reflux. *J Pediatr Urol*. 2014;10(2):344-351.
34. Cerwinka WH, Kirsch AJ. Magnetic resonance urography in pediatric urology. *Curr Opin Urol*. 2010; 20(4):323-329.
35. Kovanlikaya A, Okkay N, Cakmakci H, Ozdogan O, Degirmenci B, Kavukcu S. Comparison of MRI and renal cortical scintigraphy findings in childhood acute pyelonephritis: preliminary experience. *Eur J Radiol*. 2004; 49(1):76-80.
36. Yoo JM, Koh JS, Han CH, et al. Diagnosing Acute Pyelonephritis with CT, Tc-DMSA SPECT, and Doppler Ultrasound: A Comparative Study. *Korean J Urol* 2010;51:260-5.
37. Fontanilla T, Minaya J, Cortes C, et al. Acute complicated pyelonephritis: contrast-enhanced ultrasound. *Abdom Imaging*. 2012;37(4):639-646.
38. Kim B, Lim HK, Choi MH, et al. Detection of parenchymal abnormalities in acute pyelonephritis by pulse inversion harmonic imaging with or without microbubble ultrasonographic contrast agent: correlation with computed tomography. *J Ultrasound Med*. 2001; 20(1):5-14.
39. Mitterberger M, Pinggera GM, Colleselli D, et al. Acute pyelonephritis: comparison of diagnosis with computed tomography and contrast-enhanced ultrasonography. *BJU Int*. 2008; 101(3):341-344.
40. Kawashima A, Sandler CM, Goldman SM. Imaging in acute renal infection. *BJU Int*. 2000; 86 Suppl 1:70-79.
41. Bykov S, Chervinsky L, Smolkin V, Halevi R, Garty I. Power Doppler sonography versus Tc-99m DMSA scintigraphy for diagnosing acute pyelonephritis in children: are these two methods comparable? *Clin Nucl Med*. 2003;28(3):198-203.
42. Halevy R, Smolkin V, Bykov S, Chervinsky L, Sakran W, Koren A. Power Doppler ultrasonography in the diagnosis of acute childhood pyelonephritis. *Pediatr Nephrol*. 2004; 19(9):987-991.
43. Bafaraj SM. Value of Magnetic Resonance Urography Versus Computerized Tomography Urography (CTU) in Evaluation of Obstructive Uropathy: An Observational Study. *Curr Med Imaging Rev*. 14(1):129-134, 2018 Feb.
44. Tamm EP, Silverman PM, Shuman WP. Evaluation of the patient with flank pain and possible ureteral calculus. *Radiology* 2003;228:319-29.
45. Moore CL, Scoutt L. Sonography first for acute flank pain? *J Ultrasound Med* 2012;31:1703-11.
46. American College of Radiology. ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation. Available at: <https://gravitas.acr.org/PPTS/GetDocumentView?docId=23+&releaseId=2>.
47. American College of Radiology. ACR Committee on Drugs and Contrast Media. Manual on Contrast Media. Available at: <https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Contrast-Manual>.

48. Hill JB, Sheffield JS, McIntire DD, Wendel GD, Jr. Acute pyelonephritis in pregnancy. *Obstet Gynecol* 2005;105:18-23.
49. McAleer SJ, Loughlin KR. Nephrolithiasis and pregnancy. *Curr Opin Urol.* 2004;14(2):123-127.
50. 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.
51. Rasmussen PE, Nielsen FR. Hydronephrosis during pregnancy: a literature survey. *Eur J Obstet Gynecol Reprod Biol.* 1988;27(3):249-259.
52. Fiorentino M, Pesce F, Schena A, Simone S, Castellano G, Gesualdo L. Updates on urinary tract infections in kidney transplantation. *J Nephrol* 2019;32:751-61.
53. Granata A, Andrulli S, Fiorini F, et al. Diagnosis of acute pyelonephritis by contrast-enhanced ultrasonography in kidney transplant patients. *Nephrol Dial Transplant.* 2011;26(2):715-720.
54. Faletti R, Cassinis MC, Gatti M, et al. Acute pyelonephritis in transplanted kidneys: can diffusion-weighted magnetic resonance imaging be useful for diagnosis and follow-up?. *Abdominal Radiology.* 41(3):531-7, 2016 Mar.
55. American College of Radiology. ACR–SPR Practice Parameter for the Safe and Optimal Performance of Fetal Magnetic Resonance Imaging (MRI). Available at: <https://gravitas.acr.org/PPTS/GetDocumentView?docId=89+&releaseId=2>.
56. American College of Radiology. ACR-ACOG-AIUM-SMFM-SRU Practice Parameter for the Performance of Standard Diagnostic Obstetrical Ultrasound. Available at: <https://gravitas.acr.org/PPTS/GetDocumentView?docId=28+&releaseId=2>.
57. American College of Radiology. ACR Committee on MR Safety. 2026 ACR Manual on MR Safety. Available at: <https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Radiology-Safety/Manual-on-MR-Safety.pdf>.
58. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Appropriateness-Criteria/ACR-Appropriateness-Criteria-Radiation-Dose-Assessment-Introduction.pdf>.

## Disclaimer

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.

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