

**American College of Radiology  
ACR Appropriateness Criteria®  
Renal Transplant Dysfunction**

**Variant 1: Adult. Renal transplant dysfunction. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US duplex Doppler kidney transplant	Usually Appropriate	○
US pelvis	Usually Not Appropriate	○
US pelvis with IV contrast	Usually Not Appropriate	○
Arteriography kidney	Usually Not Appropriate	⦿⦿⦿
Fluoroscopy antegrade pyelography	Usually Not Appropriate	⦿⦿⦿
Image-guided biopsy kidney	Usually Not Appropriate	Varies
MRA abdomen and pelvis without and with IV contrast	Usually Not Appropriate	○
MRA abdomen and pelvis without IV contrast	Usually Not Appropriate	○
MRA pelvis without and with IV contrast	Usually Not Appropriate	○
MRA pelvis without IV contrast	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 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	○
MRV abdomen and pelvis without and with IV contrast	Usually Not Appropriate	○
MRV pelvis 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 pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿
CT pelvis without IV contrast	Usually Not Appropriate	⦿⦿⦿
DTPA renal scan	Usually Not Appropriate	⦿⦿⦿
MAG3 renal scan	Usually Not Appropriate	⦿⦿⦿
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CT pelvis without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTA abdomen and pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTA pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTU without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTV abdomen and pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTV pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿

**Variant 2:**

**Adult. Renal transplant dysfunction. US suspicious for, but not conclusive for, arterial etiology. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRA abdomen and pelvis without and with IV contrast	Usually Appropriate	○
MRA pelvis without and with IV contrast	Usually Appropriate	○
CTA abdomen and pelvis with IV contrast	Usually Appropriate	⦿⦿⦿⦿
CTA pelvis with IV contrast	Usually Appropriate	⦿⦿⦿⦿
US pelvis with IV contrast	May Be Appropriate	○
Arteriography kidney	May Be Appropriate (Disagreement)	⦿⦿⦿
MRA abdomen and pelvis without IV contrast	May Be Appropriate	○
MRA pelvis without IV contrast	May Be Appropriate	○
DTPA renal scan	May Be Appropriate	⦿⦿⦿
US duplex Doppler kidney transplant	Usually Not Appropriate	○
US pelvis	Usually Not Appropriate	○
Image-guided biopsy kidney	Usually Not Appropriate	Varies
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	○
MRI abdomen and pelvis 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	○
MRV abdomen and pelvis without and with IV contrast	Usually Not Appropriate	○
MRV pelvis 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 pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿
CT pelvis without IV contrast	Usually Not Appropriate	⦿⦿⦿
MAG3 renal scan	Usually Not Appropriate	⦿⦿⦿
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CT pelvis without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTU without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTV abdomen and pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTV pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿

**Variant 3:**

**Adult. Renal transplant dysfunction. US suspicious for, but not conclusive for, venous etiology.**  
**Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRV abdomen and pelvis without and with IV contrast	Usually Appropriate	○
MRV pelvis without and with IV contrast	Usually Appropriate	○
CTV abdomen and pelvis with IV contrast	Usually Appropriate	⦿⦿⦿⦿
CTV pelvis with IV contrast	Usually Appropriate	⦿⦿⦿⦿
US duplex Doppler kidney transplant	May Be Appropriate	○
US pelvis with IV contrast	May Be Appropriate (Disagreement)	○
MRI pelvis without and with IV contrast	May Be Appropriate	○
US pelvis	Usually Not Appropriate	○
Arteriography kidney	Usually Not Appropriate	⦿⦿⦿
Image-guided biopsy kidney	Usually Not Appropriate	Varies
MRA abdomen and pelvis without and with IV contrast	Usually Not Appropriate	○
MRA abdomen and pelvis without IV contrast	Usually Not Appropriate	○
MRA pelvis without and with IV contrast	Usually Not Appropriate	○
MRA pelvis without IV contrast	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 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 and pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	⦿⦿⦿
CT pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿
CT pelvis without IV contrast	Usually Not Appropriate	⦿⦿⦿
DTPA renal scan	Usually Not Appropriate	⦿⦿⦿
MAG3 renal scan	Usually Not Appropriate	⦿⦿⦿
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CT pelvis without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTA abdomen and pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTA pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTU without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿

**Variant 4:**

**Adult. Renal transplant dysfunction. US suspicious for, but not conclusive for, extrinsic etiology. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	○
MRI abdomen and pelvis without IV contrast	May Be Appropriate	○
MRI pelvis without and with IV contrast	May Be Appropriate	○
MRI pelvis without IV contrast	May Be Appropriate	○
MRU without and with IV contrast	May Be Appropriate	○
MRU without IV contrast	May Be Appropriate	○
CT abdomen and pelvis with IV contrast	May Be Appropriate	⦿⦿⦿
CT abdomen and pelvis without IV contrast	May Be Appropriate	⦿⦿⦿
CT pelvis with IV contrast	May Be Appropriate	⦿⦿⦿
CT pelvis without IV contrast	May Be Appropriate	⦿⦿⦿
CT abdomen and pelvis without and with IV contrast	May Be Appropriate	⦿⦿⦿⦿
CT pelvis without and with IV contrast	May Be Appropriate (Disagreement)	⦿⦿⦿⦿
CTU without and with IV contrast	May Be Appropriate	⦿⦿⦿⦿
US duplex Doppler kidney transplant	Usually Not Appropriate	○
US pelvis	Usually Not Appropriate	○
US pelvis with IV contrast	Usually Not Appropriate	○
Arteriography kidney	Usually Not Appropriate	⦿⦿⦿
Fluoroscopy antegrade pyelography	Usually Not Appropriate	⦿⦿⦿
Image-guided biopsy kidney	Usually Not Appropriate	Varies
MRA abdomen and pelvis without and with IV contrast	Usually Not Appropriate	○
MRA abdomen and pelvis without IV contrast	Usually Not Appropriate	○
MRA pelvis without and with IV contrast	Usually Not Appropriate	○
MRA pelvis without IV contrast	Usually Not Appropriate	○
MRV abdomen and pelvis without and with IV contrast	Usually Not Appropriate	○
MRV pelvis without and with IV contrast	Usually Not Appropriate	○
DTPA renal scan	Usually Not Appropriate	⦿⦿⦿
MAG3 renal scan	Usually Not Appropriate	⦿⦿⦿
CTA abdomen and pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTA pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTV abdomen and pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTV pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿

**Variant 5:**                      **Adult. Renal transplant dysfunction. US unremarkable or indeterminate. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
Image-guided biopsy kidney	Usually Appropriate	Varies
US duplex Doppler kidney transplant	Usually Not Appropriate	○
US pelvis	Usually Not Appropriate	○
US pelvis with IV contrast	Usually Not Appropriate	○
Arteriography kidney	Usually Not Appropriate	⦿⦿⦿
Fluoroscopy antegrade pyelography	Usually Not Appropriate	⦿⦿⦿
MRA abdomen and pelvis without and with IV contrast	Usually Not Appropriate	○
MRA abdomen and pelvis without IV contrast	Usually Not Appropriate	○
MRA pelvis without and with IV contrast	Usually Not Appropriate	○
MRA pelvis without IV contrast	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 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	○
MRV abdomen and pelvis without and with IV contrast	Usually Not Appropriate	○
MRV pelvis 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 pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿
CT pelvis without IV contrast	Usually Not Appropriate	⦿⦿⦿
DTPA renal scan	Usually Not Appropriate	⦿⦿⦿
MAG3 renal scan	Usually Not Appropriate	⦿⦿⦿
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CT pelvis without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTA abdomen and pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTA pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTU without and with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTV abdomen and pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿
CTV pelvis with IV contrast	Usually Not Appropriate	⦿⦿⦿⦿

## RENAL TRANSPLANT DYSFUNCTION

Expert Panel on Urological Imaging: Myles T. Taffel, MD<sup>a</sup>; Gaurav Khatri, MD<sup>b</sup>; Andrei S. Purysko, MD<sup>c</sup>; Ryan Avery, MD<sup>d</sup>; Melanie P. Caserta, MD<sup>e</sup>; Silvia D. Chang, MD<sup>f</sup>; Alberto Diaz De Leon, MD<sup>g</sup>; Dhakshinamoorthy Ganeshan, MBBS<sup>h</sup>; Rajan T. Gupta, MD<sup>i</sup>; Susie Q. Lew, MD<sup>j</sup>; Andrej Lyschchik, MD, PhD<sup>k</sup>; Refky Nicola, DO, MSc<sup>l</sup>; Carl Piel Jr., DO<sup>m</sup>; Alp Sener, MD, PhD<sup>n</sup>; Andrew D. Smith, MD, PhD<sup>o</sup>; Paul Nikolaidis, MD.<sup>p</sup>

### **Summary of Literature Review**

#### **Introduction/Background**

Renal transplantation into the pelvis is the preferred treatment method in patients with end-stage renal failure. Compared with maintenance dialysis, most patients who receive a successful transplant experience have an improved quality of life and a significant reduction in mortality [1]. Since 1988, over 525,000 renal transplants have been performed in the United States [2]. In 2021 alone, 24,670 renal transplants were conducted, with 5,971 originating from living donors and 18,699 from deceased donors. Despite a steady increase in the number of renal transplants each year, there remains a huge imbalance between organ availability and demand, with close to 90,000 patients on the wait list for renal transplantation. After renal transplantation, every effort is made to address allograft dysfunction by management of immunosuppression and transplant complications. Five-year survival rates for the graft in renal transplant patients range from 72% to 99%, with the best rates seen in patients receiving kidneys from living donors.

Although the timing of intrinsic renal dysfunction may aid in narrowing the differential diagnosis, significant overlap exists between the various underlying etiologies. In the immediate postoperative period (<1 week), the most common etiology of intrinsic dysfunction includes acute tubular necrosis (ATN). ATN occurs in the immediate posttransplant period in a high percentage of cadaver grafts and infrequently in living related donors. Acute rejection occurs from 1 week to 1 month after transplantation. Fortunately, acute rejection represents an uncommon occurrence in current practice [3]. Although the introduction of calcineurin inhibitors (cyclosporine and tacrolimus) has dramatically reduced the rate of acute allograft rejection, these drugs can be nephrotoxic at supratherapeutic levels [4]. Toxicity occurs most commonly in the second or third month after transplantation, when the drugs are being titrated [5]. Chronic rejection is the most common cause of late graft dysfunction and presents at least 3 months following transplantation.

Like intrinsic renal dysfunction, vascular complications and peritransplant collections are most often encountered during specific postoperative time periods. Renal artery thrombosis (RAT) and renal vein thrombosis (RVT) usually occur in the first week after transplantation. They are usually the result of technical surgical difficulties and/or clotting disorders [6]. Renal artery stenosis (RAS) represents the most common vascular complication, with an incidence of 1% to 2% [6,7]. Although it can occur at any time, RAS usually presents between 3 and 24 months following transplantation. Perigraft collections occur in ≤50% of patients following transplantation [8]. Seromas and hematomas generally occur in the first week following surgery. Abscesses and urinomas usually occur 1 to 3 weeks after transplantation. Lymphoceles typically present 1 to 2 months after transplantation [9].

Please note that this document on renal transplant evaluation assumes that there are no clinical signs or suspicion of infection because renal infection is covered in a different topic (see the ACR Appropriateness Criteria<sup>®</sup> topic on “[Acute Pyelonephritis](#)” [10]). Some local practice patterns do not routinely administer intravenous (IV) contrast to renal transplant patients. In this document, it is presumed that patients have no contraindications to IV contrast agents.

---

<sup>a</sup>New York University Langone Medical Center, New York, New York. <sup>b</sup>Panel Chair, UT Southwestern Medical Center, Dallas, Texas. <sup>c</sup>Panel Vice-Chair, Cleveland Clinic, Cleveland, Ohio. <sup>d</sup>Feinberg School of Medicine, Northwestern University, Chicago, Illinois; Commission on Nuclear Medicine and Molecular Imaging. <sup>e</sup>Mayo Clinic, Jacksonville, Florida. <sup>f</sup>University of British Columbia, Vancouver, British Columbia, Canada. <sup>g</sup>The University of Texas MD Anderson Cancer Center, Houston, Texas. <sup>h</sup>The University of Texas MD Anderson Cancer Center, Houston, Texas. <sup>i</sup>Duke University Medical Center, Durham, North Carolina. <sup>j</sup>George Washington University, Washington, District of Columbia; American Society of Nephrology. <sup>k</sup>Thomas Jefferson University Hospital, Philadelphia, Pennsylvania. <sup>l</sup>SUNY Upstate Medical University, Syracuse, New York. <sup>m</sup>UT Southwestern Medical Center, Dallas, Texas; American College of Emergency Physicians. <sup>n</sup>Western University, London, Ontario, Canada; American Urological Association. <sup>o</sup>University of Alabama at Birmingham, Birmingham, Alabama. <sup>p</sup>Specialty Chair, Northwestern University, Chicago, Illinois.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through representation of such organizations on expert panels. Participation on the expert panel does not necessarily imply endorsement of the final document by individual contributors or their respective organization.

Reprint requests to: [publications@acr.org](mailto:publications@acr.org)

## 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 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 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 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.

Contrast-enhanced ultrasound (CEUS) technique (pertaining to US pelvis with IV contrast procedure in this document) employs off-label injection of IV contrast agents and use of specific US software to allow contrast visualization [11,12]. The microbubble contrast agent remains intravascular and is excreted via respiration, resulting in a safety profile that is superior to that of CT and MRI contrast agents. A rapid, real-time study that can be performed at the bedside, CEUS allows dynamic observation of perfusion that is not possible on CT or MRI. The perfusion time of 2 to 3 minutes provides an opportunity to reinject more contrast, if required.

## 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: Adult. Renal transplant dysfunction. Initial imaging.

#### Arteriography Kidney

There is no current literature specific to the use of arteriography of the kidney in the initial evaluation of a renal transplant. This modality is invasive with an increased risk of thromboembolism leading to graft dysfunction, groin hematomas, pseudoaneurysm (PSA), or traumatic arteriovenous fistula (AVF).

#### CT Abdomen and Pelvis With IV Contrast

There is no current literature specific to the use of CT of the abdomen and pelvis with IV contrast in the initial evaluation of a renal transplant. The examination is rarely performed when rejection or ATN diagnosis is being considered because the imaging findings are nonspecific. It may be beneficial in detecting hydronephrosis and/or nephrolithiasis. It is also useful in the evaluation of renal masses, perinephric fluid collections, and posttransplant lymphoproliferative disease. The abdominal component may be beneficial to evaluate for other postoperative complications such as small bowel obstruction.



### **CT Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis without and with IV contrast in the initial evaluation of a renal transplant. It may be beneficial in detecting hydronephrosis and/or nephrolithiasis. It is also useful in the evaluation of large vessel vascular abnormalities, renal masses, perinephric fluid collections, and posttransplant lymphoproliferative disease. The abdominal component may be beneficial to evaluate the native kidneys or to evaluate for other postoperative complications such as small bowel obstruction.

### **CT Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis without IV contrast in the initial evaluation of a renal transplant. The study may be helpful in patients with suspected hemorrhage or in the evaluation for urinary obstruction and/or nephrolithiasis in the transplant kidney. It also may be useful to define the extent of a peritransplant fluid collection. The abdominal component may be beneficial to evaluate for other postoperative complications such as small bowel obstruction.

### **CT Pelvis With IV Contrast**

There is no current literature specific to the use of CT of the pelvis with IV contrast in the initial evaluation of a renal transplant. The examination is rarely performed when rejection or ATN are being considered because the imaging findings are nonspecific. It may be beneficial in detecting hydronephrosis and/or nephrolithiasis. It is also useful in the evaluation of renal masses, perinephric fluid collections, and posttransplant lymphoproliferative disease.

### **CT Pelvis Without and With IV Contrast**

There is no current literature specific to the use of CT of the pelvis without and with IV contrast in the initial evaluation of a renal transplant.

### **CT Pelvis Without IV Contrast**

There is no current literature specific to the use of CT of the pelvis without IV contrast in the initial evaluation of a renal transplant. The study may be helpful in patients with suspected hemorrhage or in the evaluation for urinary obstruction and/or nephrolithiasis in the transplant kidney. It also may be useful to define the extent of a peritransplant fluid collection.

### **CTA Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CT angiography (CTA) of the abdomen and pelvis with IV contrast in the initial evaluation of a renal transplant.

### **CTA Pelvis With IV Contrast**

There is no current literature specific to the use of CTA of the pelvis with IV contrast in the initial evaluation of a renal transplant.

### **CTU Without and With IV Contrast**

There is no current literature specific to the use of CTU without and with IV contrast of the pelvis in the initial evaluation of a renal transplant.

### **CTV Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CT venography (CTV) of the abdomen and pelvis with IV contrast in the initial evaluation of a renal transplant.

### **CTV Pelvis With IV Contrast**

There is no current literature specific to the use of CTV of the pelvis with IV contrast in the initial evaluation of a renal transplant.

### **DTPA Renal Scan**

Dynamic renal scintigraphy (DRS) can provide a noninvasive means to evaluate renal transplant function qualitatively and also screens for surgical complications. Renography has the advantage of providing functional information, whereas serum creatinine levels lag behind function and radiographic studies capture primarily anatomical changes. Although sensitive in the detection of graft dysfunction, scintigraphic parameters do not yield sufficient diagnostic power for a specific diagnosis. Like US resistive indices (RI), renogram changes do not contribute to the differential diagnosis between acute rejection, ATN, and cyclosporine toxicity [13,14].

Tc-99m diethylenetriamine pentaacetic acid (DTPA) represents a radiopharmaceutical that can monitor the transplant kidneys perfusion (blood flow) and uptake (glomerular filtration rate). Unlike Tc-99m



mercaptoacetyltriglycine (MAG3), DTPA is not excreted; therefore, the agent is limited in the evaluation for obstruction, only demonstrating early impact on glomerular filtration. In patients with renal allograft dysfunction, DTPA perfusion patterns are more sensitive in diagnosing transplant dysfunction when compared to MAG3 [15]. Diuretic renography can be acceptable in more acute and less severe patients with obstruction, but the MAG3 is preferred due to its tubular secretion.

The scintigraphic findings for RAS appear similar to those seen with mild rejection. Angiotensin-converting enzyme inhibitor renography can aid in the diagnosis if baseline studies are available for comparison. Absence of perfusion and uptake in the transplant is nonspecific but can be seen in RAT or RVT [16].

There are no large studies comparing DTPA to other noninvasive or invasive procedures in the initial evaluation of a renal transplant. As an adjunct to a baseline US, there are still centers that routinely perform DRS before patient discharge from the hospital to serve as a baseline study for future comparison [17]. Although used routinely in the 1990s for baseline establishment, the more recent European Association of Urology (EAU) guidelines do not recommend routine DRS in the evaluation of renal function in patients with kidney transplants [18].

### **Fluoroscopy Antegrade Pyelography**

There is no current literature specific to the use of fluoroscopic antegrade pyelography in the initial evaluation of a renal transplant.

### **Image-Guided Biopsy Kidney**

There is no current literature specific to the use of image-guided kidney biopsy in the initial evaluation of a renal transplant. This intervention may be appropriate in subsequent evaluations.

### **MAG3 Renal Scan**

DRS can be valuable in renal transplantation evaluation because it can provide a noninvasive means to evaluate transplant function qualitatively and also screen for surgical complications. Renography has the advantage of providing functional information, whereas serum creatinine levels lag behind function and radiographic studies capture primarily anatomical changes. Although sensitive in the detection of graft dysfunction, scintigraphic parameters do not yield sufficient diagnostic power for a specific diagnosis. Like RI, renogram changes do not contribute to the differential diagnosis between acute rejection, ATN, and cyclosporine toxicity [13,14,19].

DRS using MAG3 can assess the 3 sequential phases of renal function (renal perfusion, renal excretion, and urine flow) [20]. The scintigraphic findings for RAS appear similar to those seen with mild rejection. Angiotensin-converting enzyme inhibitor renography can aid in the diagnosis if baseline studies are available for comparison. Absence of perfusion and uptake in the transplant is nonspecific but can be seen in renal artery or RVT. Because of its tubular secretion, MAG3 can be used to assess the flow of urine and could serve as an adjunct to US. In the setting of hydronephrosis identified on US, MAG3 diuretic renography assess the functional significance [21]. The finding of a normal or slowly declining activity curve in the third phase has an excellent negative predictive value and permits confident exclusion of obstruction; however, false-positives may occur in patients with ATN, dehydration, or poor renal function. The agent may also be helpful in differentiation between a urinoma and other posttransplant fluid collections (lymphocele, seroma, abscess, hematoma).

There are no large studies comparing MAG3 to other noninvasive or invasive procedures in the initial evaluation of a renal transplant. As an adjunct to a baseline US, there are still centers that routinely perform DRS before patient discharge from the hospital to serve as a baseline study for future comparison [17]. Although used routinely in the 1990s for baseline establishment, the recent EAU guidelines do not recommend routine DRS in the evaluation of renal function in patients with kidney transplants [18].

### **MRA Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MR angiography (MRA) abdomen and pelvis without and with IV contrast in the initial evaluation of a renal transplant.

### **MRA Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of MRA abdomen and pelvis without IV contrast in the initial evaluation of a renal transplant.

### **MRA Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRA pelvis without and with IV contrast in the initial evaluation of a renal transplant.

**MRA Pelvis Without IV Contrast**

There is no current literature specific to the use of MRA pelvis without IV contrast in the initial evaluation of a renal transplant.

**MRI Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRI abdomen and pelvis without and with IV contrast in the initial evaluation of a renal transplant.

**MRI Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of MRI abdomen and pelvis without IV contrast in the initial evaluation of a renal transplant.

**MRI Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRI pelvis without and with IV contrast in the initial evaluation of a renal transplant.

**MRI Pelvis Without IV Contrast**

There is no current literature specific to the use of MRI without IV contrast in the initial evaluation of a renal transplant.

**MRU Without and With IV Contrast**

There is no current literature specific to the use of MRU without and with IV contrast in the initial evaluation of a renal transplant.

**MRU Without IV Contrast**

There is no current literature specific to the use of MRU without IV contrast in the initial evaluation of a renal transplant.

**MRV Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRV abdomen and pelvis without and with IV contrast in the initial evaluation of a renal transplant.

**MRV Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRI pelvis without and with IV contrast in the initial evaluation of a renal transplant.

**US Duplex Doppler Kidney Transplant**

Because renal transplants typically are located anteriorly in the pelvis, they are usually readily examined with US. US is routinely used to evaluate the transplant within the first 24 hours after transplantation and also serves as the first-line evaluation method following the onset of transplant dysfunction. Grayscale images are obtained to evaluate for transplant size, echotexture, hydronephrosis, peritransplant fluid collections, and masses and to measure renal cortical thickness. The adjacent bladder is also evaluated. Color Doppler images evaluate the patency and direction of flow in transplant arteries and veins. Spectral analysis of vascular waveforms and velocities can provide information about a range of pathologies, including RAS and RVT. US offers the advantage of being fast, portable, and performed in real time.

Renal segmental or intralobar artery RI, measured by duplex Doppler US, are often used as a nonspecific parameter for allograft dysfunction. Although RI values differ between normal and abnormal allografts, studies have suggested that the RI is neither sensitive nor specific in identifying the cause of transplant dysfunction [22,23]. Studies have found a high specificity of 91% to 100% and variable positive predictive value of 29% to 100%, albeit with low sensitivity (9%-13%) for diagnosis of allograft rejection based on a RI >0.9 [24,25]. Previous studies have shown that renal arterial RI can also be useful in predicting graft survival [26]. Radermacher et al [26] found that 47% of patients with RI >0.80 at 3 months after transplantation developed chronic allograft nephropathy, compared to 9% of patients with RI <0.80. McArthur et al [27] found that both RI and pulsatility index measured between week 1 and 3 months significantly correlated with the 1 year estimated glomerular filtration rate.

Although a RI >0.80 was initially thought to correlate with allograft dysfunction, a study by Naesens et al [28] raised doubt on this theory. Their single-center prospective study analyzed RI at the time of protocol-specified renal allograft biopsies and in patients with graft dysfunction. Patients with RI >0.80 did have a 4.12 times higher mortality at 24 months than those <0.80, but their need for dialysis did not differ. The RI was significantly higher at the time of biopsy performed in patients with graft dysfunction, but changes in the RI did not reflect changes in

histologic features when biopsies were performed at protocol-specific time points. The authors surmised that these changes did not reflect an underlying intrarenal disease process but were related to patient age and central hemodynamic factors. This complex interaction of co-existing factors in renal transplants makes the interpretation of Doppler parameters difficult.

Doppler US remains the first-line noninvasive tool in the assessment of suspected RAS and uses a combination of direct evaluation of the anastomosis and main renal artery in addition to indirect evaluation for stenosis based on intrarenal waveform morphology. Peak systolic velocity (PSV) in the renal artery is commonly used as the parameter to assess for the presence of RAS on US. Cutoff values of 200 to 300 cm/s have been proposed in various studies [29,30], but the lower limit suffers from low specificity, leading to unnecessary angiography procedures [31]. In a study by de Moraes et al [32], they reported a sensitivity of 90% to 96.8% and a specificity of 87.5% to 70% for detection of RAS using various PSV thresholds in the main renal artery and a sensitivity of 100% and specificity of 96.7% using an acceleration time of  $>0.09$ . Another parameter that can be used is the renal artery to iliac artery ratio, which has been shown to have a sensitivity of 90% and a specificity of 96.7% using a cutoff value of 1.8. Alternatively, AbuRahma et al [33] found that a PSV of 285 cm/s or renal-aortic ratio of 3.7 alone was better than any combination of PSVs, end-diastolic velocities, or renal-aortic ratios in detecting  $\geq 60\%$  stenosis. Fananapazir et al [34] used 3 US factors (highest renal artery velocity  $> 300$  cm/s, presence of spectral broadening, and acceleration time  $>0.1$  s) to stratify patients into low, intermediate, high, and very high risk for RAS. The model demonstrated a 96% sensitivity and 91% specificity in classifying no stenosis versus any stenosis.

US provides a very useful in the detection of vascular thrombosis. The US appearance of RAT is striking, with complete absence of flow in the renal vessels on color flow and spectral analysis. Power Doppler imaging may be helpful because of its capability to detect low flow. However, it is important to remember that the absence of arterial flow within the kidney can also be seen in patients with hyperacute rejection and RVT [35]. Absence of renal venous flow on US with renal enlargement is highly specific for RVT. Reversal of flow in the renal artery in diastole is often found in association with RVT [36]; however, this represents only approximately 10% of cases of reversed diastolic flow. Reversal of flow is seen more commonly in rejection or ATN and occasionally with nephrosclerosis [37].

US is also a useful tool in the detection of PSAs and AVFs, which may occur after biopsy. Although these complications resolve spontaneously in most cases, they can affect allograft function if they are large.

The EAU guidelines provide a strong recommendation rating to perform a US as the initial examination to evaluate for causes of graft dysfunction including vascular complications and obstruction [18]. This can also serve as a baseline examination for future comparison.

### **US Pelvis**

There is no current literature specific to the use of an US pelvis in the initial evaluation of a renal transplant as this examination does not specifically include evaluation of the renal transplant.

### **US Pelvis With IV Contrast**

There is no current literature specific to the use of CEUS pelvis in the initial evaluation of a renal transplant.

### **Variant 2: Adult. Renal transplant dysfunction. US suspicious for, but not conclusive for, arterial etiology. Next imaging study.**

This variant assumes that the initial US was performed with sufficient technology, appropriate technique, and that the images were interpreted by experts.

### **Arteriography Kidney**

RAS occurs in 1% to 23% of patients following transplantation and accounts for 1% to 5% of renal transplant hypertension [38-40]. RAS management includes percutaneous therapeutic angioplasty and stenting, with a success rate of 65% to 100% [41-52]. The complication rate from percutaneous therapeutic angioplasty and stenting of 0% to 10% is low compared to surgery, which has a graft loss rate of 15% and mortality rate of 5%.

Renal biopsy may result in AVF. The reported incidence of AVF following biopsy ranges from 6% to 10% [53], but 90% of these have a benign course [54] with 70% of these spontaneously resolving within 1 to 2 years. If clinically significant (major bleeding, systemic hypertension, or graft impairment) angiography with selective embolization would be the first course of management.

There is no current literature specific to the use of kidney arteriography in a patient with suspicion for an arterial etiology. The modality should be heavily considered if subsequent intervention is expected.

#### **CT Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis with IV contrast in a patient with suspicion for an arterial etiology.

#### **CT Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis without and with IV contrast in a patient with suspicion for an arterial etiology.

#### **CT Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis without IV contrast in a patient with suspicion for an arterial etiology.

#### **CT Pelvis With IV Contrast**

There is no current literature specific to the use of CT of the pelvis with IV contrast in a patient with suspicion for an arterial etiology.

#### **CT Pelvis Without and With IV Contrast**

There is no current literature specific to the use of CT of the pelvis without and with IV contrast in a patient with suspicion for an arterial etiology.

#### **CT Pelvis Without IV Contrast**

There is no current literature specific to the use of CT of the pelvis without IV contrast in a patient with suspicion for an arterial etiology.

#### **CTA Abdomen and Pelvis With IV Contrast**

In patients with suspected vascular complications (RAT, RAS, PSA, AVF), CTA can provide a detailed anatomic depiction before undergoing percutaneous angiography. Similar to the evaluation in native kidneys [55], the high spatial resolution of CT provides high sensitivity and specificity in the diagnosis of RAS. The abdominal component allows evaluation of the abdominal aorta. Although CTA of the abdomen and pelvis is routinely used to visualize the aorta and other upper abdominal organs, some facilities may only perform a CTA of the pelvis. There are no large studies comparing CTA abdomen and pelvis with IV contrast to other noninvasive or invasive procedures in the initial evaluation of a patient with suspicion for an arterial etiology. The EAU guidelines suggest consideration of an MRA or CTA following an unremarkable or indeterminate renal US in patients with suspected RAS [18].

#### **CTA Pelvis With IV Contrast**

In patients with suspected vascular complications (RAT, RAS, PSA, AVF), CTA can provide a detailed anatomic depiction before undergoing percutaneous angiography. Similar to the evaluation in native kidneys [55], the high spatial resolution of CT provides high sensitivity and specificity in the diagnosis of RAS. Many facilities will perform a CTA of the abdomen in addition to the pelvis because it allows visualization of the abdominal aorta and upper abdominal organs. In a small study by Helck et al [56], 42% of the vascular complications encountered on multiphase CT were not initially adequately detected on US. With comparison to arteriography, a small series by Gaddikeri et al [57] demonstrated little difference between CTA of the pelvis and MRA in the assessment of transplant RAS. There are no large studies comparing CTA pelvis with IV contrast to other noninvasive or invasive procedures in the initial evaluation of a patient with suspicion for an arterial etiology. The EAU guidelines suggest consideration of a MRA or CTA following an unremarkable or indeterminate renal US in patients with suspected RAS [18].

#### **CTU Without and With IV Contrast**

There is no current literature specific to the use of CTU without and with IV contrast in a patient with suspicion for an arterial etiology.

#### **CTV Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CTV of the abdomen and pelvis without IV contrast in a patient with suspicion for an arterial etiology.

#### **CTV Pelvis With IV Contrast**

There is no current literature specific to the use of CTV of the pelvis without IV contrast in a patient with suspicion for an arterial etiology.

### **DTPA Renal Scan**

Captopril-enhanced DTPA scintigraphy can be used to screen for possible transplant RAS. Because overlap exists in the imaging findings in patients with mild acute rejection, comparison with a baseline study is required. Absence of perfusion and uptake in the transplant is nonspecific but can be seen in RAT or RVT [16]. There is no current literature specific to the use of DTPA renal scan in a patient with suspicion for an arterial etiology.

### **Image-Guided Biopsy Kidney**

There is no current literature specific to the use of an image-guided renal transplant biopsy in a patient with suspicion for an arterial etiology.

### **MAG3 Renal Scan**

Captopril-enhanced DTPA scintigraphy can be used to screen for possible transplant RAS. Because overlap exists in the imaging findings in patients with mild acute rejection, comparison with a baseline study is required. In a small study comparing MAG3 scintigraphy to renal artery angiography as the reference standard, Mousa et al [58] reported a sensitivity of 92%, a specificity of 64%, and an accuracy of 77%. The imaging appearance of RAT is indistinguishable from RVT on scintigraphy [59].

### **MRA Abdomen and Pelvis Without and With IV Contrast**

MRA permits a noninvasive method to evaluate for vascular complications. Omary et al [60] found that MRA resulted in a change in the referring clinician's initial diagnostic impression in approximately 65% of patients. In 39% of patients, angiography was avoided. Sharafuddin et al [61] studied both native and transplant renal arteries and found that preprocedural planning with the use of gadolinium-enhanced MRA significantly reduced the iodinated contrast material requirement during percutaneous renal artery interventions, in addition to shortening the procedure duration.

Unfortunately, MRA suffers from a few pitfalls that may lead to a false diagnosis of stenosis or an overestimation of a stenosis related to metallic artifact or venous contamination [62]. In addition to depicting areas of stenosis in the main renal artery, MRA is able to depict areas of infarction within the kidney, which are seen as areas of heterogeneous T1 and T2 signal intensity and as focal areas of nonenhancement on the postcontrast images. Using 3-D gadolinium-enhanced MRA of the lower abdomen and pelvis for the detection of transplant RAS, Ismaeel et al [63] showed a sensitivity of 93.7%, a specificity of 80%, and an accuracy of 88.5% when compared to angiography. The abdominal component allows evaluation of the abdominal aorta. The EAU guidelines provide a strong recommendation rating to perform a MRA or CTA following an unremarkable or indeterminate renal US in patients with suspected RAS [18].

### **MRA Abdomen and Pelvis Without IV Contrast**

MRA permits a noninvasive method to evaluate for vascular complications. Although routinely used macrocyclic gadolinium-based contrast agents (GBCAs) have a very low risk for development of nephrogenic systemic fibrosis (NSF), noncontrast MRA with steady-state free precession imaging can be of use in patients with strong contraindications to GBCAs [64]. Multiple studies have revealed excellent image quality and good interobserver reader agreement when noncontrast techniques are implemented [64-68], although studies have shown that noncontrast MRA can overestimate the degree of transplant RAS [64,67,68]. A small study by Lanzman et al [65] comparing noncontrast MRA to digital subtraction angiography in detection of relevant RAS reported that the sensitivity, specificity, and accuracy were 100%, 88% and 91%, respectively. Unfortunately, MRA suffers from a few pitfalls that may lead to a false diagnosis of stenosis or an overestimation of a stenosis related to metallic artifact or venous contamination [62]. The abdominal component allows evaluation of the abdominal aorta.

### **MRA Pelvis Without and With IV Contrast**

Although angiography remains the reference standard for the anatomic delineation of the renal arteries, MRA permits a noninvasive method to evaluate for vascular complications. Omary et al [60] found that MRA resulted in a change in the referring clinician's initial diagnostic impression in approximately 65% of patients. In 39% of patients, angiography was avoided. Sharafuddin et al [61] studied both native and transplant renal arteries and found that preprocedural planning with the use of gadolinium-enhanced MRA significantly reduced the iodinated contrast material requirement during percutaneous renal artery interventions, in addition to shortening the procedure duration.

Unfortunately, MRA suffers from a few pitfalls that may lead to a false diagnosis of stenosis or an overestimation of a stenosis. These include artifacts caused by metallic surgical clips near the transplant artery that result in signal loss near the artery, giving the false impression of stenosis. Venous contamination due to inaccurate timing of the

arterial bolus is another artifact that can affect the accuracy of diagnosis. Careful evaluation of the source images and multiplanar reformats will help solve these problems [62]. In addition to depicting areas of stenosis in the main renal artery, MRA is able to depict areas of infarction within the kidney, which are seen as areas of heterogeneous T1 and T2 signal intensity and as focal areas of nonenhancement on the postcontrast images. Using 3-D gadolinium-enhanced MRA for the detection of transplant RAS, Ismaeel et al [63] showed a sensitivity of 93.7%, a specificity of 80%, and an accuracy of 88.5% when compared to angiography. With comparison to arteriography, a small series by Gaddikeri et al [57] demonstrated little difference between CTA and MRA in the assessment of transplant RAS. The EAU guidelines suggest consideration of an MRA or CTA following an unremarkable or indeterminate renal US in patients with suspected RAS [18].

#### **MRA Pelvis Without IV Contrast**

MRA permits a noninvasive method to evaluate for vascular complications. Although routinely used macrocyclic GBCAs have a very low risk for development of NSF, noncontrast MRA with steady-state free precession imaging can be of use in patients with strong contraindications to GBCAs [64]. Multiple studies have revealed excellent image quality and good interobserver reader agreement when noncontrast techniques are implemented [64-68]. Studies have shown that noncontrast MRA can overestimate the degree of transplant RAS [64,67,68]. A small study by Lanzman et al [65] comparing noncontrast MRA to digital subtraction angiography in detection of relevant RAS reported sensitivity, specificity, and accuracy were 100%, 88%, and 91%, respectively. Unfortunately, MRA suffers from a few pitfalls that may lead to a false diagnosis of stenosis or an overestimation of a stenosis related to metallic artifact or venous contamination [62]. The EAU guidelines suggest consideration of an MRA or CTA following an unremarkable or indeterminate renal US in patients with suspected RAS [18].

#### **MRI Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRI abdomen and pelvis without and with IV contrast in the initial evaluation of a patient with suspicion for an arterial etiology.

#### **MRI Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of MRI abdomen and pelvis without IV contrast in the initial evaluation of a patient with suspicion for an arterial etiology.

#### **MRI Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRI pelvis without and with IV contrast in the initial evaluation of a patient with suspicion for an arterial etiology.

#### **MRI Pelvis Without IV Contrast**

There is no current literature specific to the use of MRI pelvis without IV contrast in the initial evaluation of a patient with suspicion for an arterial etiology.

#### **MRU Without and With IV Contrast**

There is no current literature specific to the use of MRU without and with IV contrast in the evaluation of a patient with suspicion for an arterial etiology.

#### **MRU Without IV Contrast**

There is no current literature specific to the use of MRU without IV contrast in the evaluation of a patient with suspicion for an arterial etiology.

#### **MRV Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRV abdomen and pelvis without and with IV contrast in the evaluation of a patient with suspicion for an arterial etiology.

#### **MRV Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRV pelvis without and with IV contrast in the evaluation of a patient with suspicion for an arterial etiology.

#### **US Duplex Doppler Kidney Transplant**

There is no current literature specific to the use of repeat US duplex Doppler kidney transplant in the evaluation of a renal transplant with suspicion for an arterial etiology based on initial US duplex Doppler studies. It is usually not useful to repeat this study, assuming that the initial US was appropriate in quality and technique. Under these circumstances, US should not be repeated.

## **US Pelvis**

There is no current literature specific to the use of a US pelvis in the initial evaluation of a renal transplant because this examination does not include evaluation of the renal transplant.

## **US Pelvis With IV Contrast**

In limited studies, CEUS provides improved accuracy over US duplex Doppler kidney transplant in diagnosing RAS. Pan et al [69] demonstrated significantly higher specificity (95.7%) on CEUS compared to Doppler derived indices on conventional US (76.1%), with equal sensitivity. This reduction in false-positives allows patients to avoid unnecessary CTAs, MRAs, and/or arteriography. Although the color Doppler findings of RAT are nonspecific (absence of flow in the main renal artery and intrarenal arteries) and can be seen in acute rejection and RVT, CEUS confirms the diagnosis with the absence of renal arterial contrast opacification, can better delineates the site and extent of thrombosis, and demonstrates areas of parenchymal ischemia/infarct. AVF can also be confirmed by CEUS and allows assessment of adjacent parenchymal flow [70].

## **Variant 3: Adult. Renal transplant dysfunction. US suspicious for, but not conclusive for, venous etiology. Next imaging study.**

This variant assumes that the initial US was performed with sufficient technology, appropriate technique, and that the images were interpreted by experts.

## **Arteriography Kidney**

There is no current literature specific to the use of kidney arteriography in a renal transplant with suspicion for a venous etiology. Given its invasive nature, the modality should be primarily employed if there is consideration for catheter-directed thrombectomy and thrombolysis [71].

## **CT Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis with IV contrast in a renal transplant with suspicion for a venous etiology. The contrast bolus timing for a conventional CT of the abdomen and pelvis may prevent optimal opacification of the venous system and thus limit evaluation for thrombus formation.

## **CT Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis without and with IV contrast in a renal transplant with suspicion for a venous etiology.

## **CT Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis without IV contrast in a renal transplant with suspicion for a venous etiology.

## **CT Pelvis With IV Contrast**

There is no current literature specific to the use of CT of the pelvis with IV contrast in a renal transplant with suspicion for a venous etiology. The contrast bolus timing for a conventional CT of the pelvis may prevent optimal opacification of the venous system and thus limit evaluation for thrombus formation. The inferior vena cava will not be completely evaluated in the absence of abdominal imaging.

## **CT Pelvis Without and With IV Contrast**

There is no current literature specific to the use of CT of the pelvis without and with IV contrast in a renal transplant with suspicion for a venous etiology.

## **CT Pelvis Without IV Contrast**

There is no current literature specific to the use of CT of the pelvis without IV contrast in a renal transplant with suspicion for a venous etiology.

## **CTA Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CTA of the abdomen and pelvis with IV contrast in a renal transplant with suspicion for a venous etiology. The contrast bolus timing for a CTA will prevent optimal opacification of the venous system and thus limit evaluation for thrombus formation.

## **CTA Pelvis With IV Contrast**

There is no current literature specific to the use of CTA of the pelvis with IV contrast in a renal transplant with suspicion for a venous etiology. The contrast bolus timing for a CTA will prevent optimal opacification of the



venous system and thus limit evaluation for thrombus formation. The inferior vena cava will not be completely evaluated in the absence of abdominal imaging.

#### **CTU Without and With IV Contrast**

There is no current literature specific to the use of CTU without and with IV contrast in a renal transplant with suspicion for a venous etiology.

#### **CTV Abdomen and Pelvis With IV Contrast**

A CTV permits improved opacification of the transplant renal vein and draining venous vasculature allowing evaluation for thrombosis. The abdominal component also allows evaluation of the inferior vena cava.

#### **CTV Pelvis With IV Contrast**

A CTV permits improved opacification of the transplant renal vein and draining venous vasculature allowing evaluation for thrombosis. The inferior vena cava will not be completely evaluated in the absence of abdominal imaging.

#### **DTPA Renal Scan**

There is no relevant literature documenting the additional benefit of DTPA renal scan after a US suspicious for a venous etiology. The scintigraphic findings are indistinguishable from RAT [59].

#### **Image-Guided Biopsy Kidney**

There is no current literature specific to the use of image-guided kidney biopsy in a renal transplant with suspicion for a venous etiology. An image-guided biopsy is not beneficial in a renal transplant with suspicion for a venous etiology.

#### **MAG3 Renal Scan**

There is no relevant literature documenting the additional benefit of MAG3 renal scan after a US suspicious for a venous etiology. The scintigraphic findings are indistinguishable from RAT [59].

#### **MRA Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRA abdomen and pelvis without and with IV contrast in a renal transplant with suspicion for a venous etiology. The contrast bolus timing for an MRA will prevent optimal opacification of the venous system and thus limit evaluation for thrombus formation.

#### **MRA Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of MRA abdomen and pelvis without IV contrast in a renal transplant with suspicion for a venous etiology.

#### **MRA Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRA pelvis without and with IV contrast in a renal transplant with suspicion for a venous etiology. The contrast bolus timing for a MRA will prevent optimal opacification of the venous system and thus limit evaluation for thrombus formation. The inferior vena cava will not be completely evaluated in the absence of abdominal imaging.

#### **MRA Pelvis Without IV Contrast**

There is no current literature specific to the use of MRA pelvis without IV contrast in a renal transplant with suspicion for a venous etiology.

#### **MRI Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRI abdomen and pelvis without and with IV contrast in a renal transplant with suspicion for a venous etiology.

#### **MRI Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of MRI abdomen and pelvis without IV contrast in a renal transplant with suspicion for a venous etiology. The contrast bolus timing for a conventional MRI of the pelvis may prevent optimal opacification of the venous system and thus limit evaluation for thrombus formation when compared to a MRV. The inclusion of the abdomen is preferred because this component allows for evaluation of the inferior vena cava.

#### **MRI Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRI pelvis without and with IV contrast in a renal transplant with suspicion for a venous etiology. The contrast bolus timing for a conventional MRI of the pelvis may prevent

optimal opacification of the venous system and thus limit evaluation for thrombus formation when compared to a MRV.

#### **MRI Pelvis Without IV Contrast**

There is no current literature specific to the use of MRI pelvis without IV contrast in a renal transplant with suspicion for a venous etiology.

#### **MRU Without and With IV Contrast**

There is no current literature specific to the use of MRU without and with IV contrast in a renal transplant with suspicion for a venous etiology.

#### **MRU Without IV Contrast**

There is no current literature specific to the use of MRU without IV contrast in a renal transplant with suspicion for a venous etiology.

#### **MRV Abdomen and Pelvis Without and With IV Contrast**

MRV permits improved visualization of the transplant renal vein and draining venous vasculature allowing evaluation for thrombosis. The abdominal component also allows evaluation of the inferior vena cava.

#### **MRV Pelvis Without and With IV Contrast**

MRV permits improved visualization of the transplant renal vein and draining venous vasculature allowing evaluation for thrombosis.

#### **US Duplex Doppler Kidney Transplant**

There is no current literature specific to the use of repeat duplex Doppler kidney transplant US in a renal transplant with suspicion for a venous etiology based on initial duplex Doppler US. It is usually not useful to repeat this study, assuming that the initial US was appropriate in quality and technique. Under these circumstances, US should not be repeated.

#### **US Pelvis**

There is no current literature specific to the use of a US pelvis in the initial evaluation of a renal transplant with suspicion for a venous etiology because this examination does not include evaluation of the renal transplant.

#### **US Pelvis With IV Contrast**

There is no current literature specific to the use of a CEUS pelvis in the in the evaluation of a renal transplant with suspicion for a venous etiology. The usefulness of CEUS to identify and define extent of the thrombus and demonstrate areas of parenchymal ischemia or infarct has been described but has not been validated in the literature.

#### **Variant 4: Adult. Renal transplant dysfunction. US suspicious for, but not conclusive for, extrinsic etiology. Next imaging study.**

This variant assumes that the initial US was performed with sufficient technology, appropriate technique, and that the images were interpreted by experts.

Extrinsic etiologies include peritransplant collections (urinoma, lymphocele, and abscess), peritransplant hematomas, malignancies unrelated to the renal parenchyma (eg, lymphoproliferative processes), and pathologic processes unrelated to the renal transplant.

#### **Arteriography Kidney**

There is no current literature specific to the use of arteriography of the kidney in a renal transplant with suspicion of an extrinsic etiology. Arteriography could identify active bleeding into a perinephric hematoma or enhancement of a perinephric mass. The modality is invasive with an increased risk of thromboembolism leading to irreversible graft dysfunction, groin hematomas, PSA, or traumatic AVF.

#### **CT Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis with IV contrast in a renal transplant with suspicion of an extrinsic etiology. It may be beneficial in detecting hydronephrosis and/or nephrolithiasis. It is also useful in the evaluation of renal masses, perinephric fluid collections, and posttransplant lymphoproliferative disease. The abdominal component may be beneficial to evaluate for other postoperative complications such as small bowel obstruction.

### **CT Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis without and with IV contrast in a renal transplant with suspicion of an extrinsic etiology. It may be beneficial in detecting hydronephrosis and/or nephrolithiasis. It is also useful in the evaluation of large vessel vascular abnormalities, renal masses, perinephric fluid collections, and posttransplant lymphoproliferative disease. The abdominal component may be beneficial to evaluate the native kidneys or to evaluate for other postoperative complications such as small bowel obstruction. It is unlikely that imaging before and after IV contrast offers increased diagnostic value compared to a single acquisition.

### **CT Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis without IV contrast in a renal transplant with suspicion of an extrinsic etiology. The study may be helpful in patients with suspected hemorrhage or in the evaluation for urinary obstruction and/or nephrolithiasis in the transplant kidney. It also may be useful to define the extent of a peritransplant fluid collection. The abdominal component may be beneficial to evaluate for other postoperative complications such as small bowel obstruction.

### **CT Pelvis With IV Contrast**

There is no current literature specific to the use of CT of the pelvis with IV contrast in a renal transplant with suspicion of an extrinsic etiology. It may be beneficial in detecting hydronephrosis and/or nephrolithiasis. It is also useful in the evaluation of renal masses, perinephric fluid collections, and posttransplant lymphoproliferative disease.

### **CT Pelvis Without and With IV Contrast**

There is no current literature specific to the use of CT of the pelvis without and with IV contrast in a renal transplant with suspicion of an extrinsic etiology. The study may be helpful in patients with suspected hemorrhage or in the evaluation for nephrolithiasis in the transplant kidney. It may be also beneficial in evaluating perinephric fluid collections or posttransplant lymphoproliferative disease.

### **CT Pelvis Without IV Contrast**

There is no current literature specific to the use of CT of the pelvis without IV contrast in a renal transplant with suspicion of an extrinsic etiology. The study may be helpful in patients with suspected hemorrhage or in the evaluation for urinary obstruction and/or nephrolithiasis in the transplant kidney. It also may be useful to define the extent of a peritransplant fluid collection.

### **CTA Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CTA of the abdomen and pelvis with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **CTA Pelvis With IV Contrast**

There is no current literature specific to the use of CTA of the pelvis with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **CTU Without and With IV Contrast**

The addition of CTU sequences allows further evaluation of the renal transplant collecting system. With IV contrast, the excretory phase permits the anatomic and functional assessment of urologic complications. A small study by Sciascia et al [72] demonstrated 90% accuracy in depicted urologic complications following kidney transplant.

### **CTV Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CTV of the abdomen and pelvis with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **CTV Pelvis With IV Contrast**

There is no current literature specific to the use of CTV of the pelvis with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **DTPA Renal Scan**

There is no current literature specific to the use of DTPA renal scan in the evaluation of a renal transplant with suspicion of an extrinsic etiology. Scintigraphy may be helpful in differentiating a urinoma from other perinephric collections such as a lymphocele or hematoma.

### **Fluoroscopy Antegrade Pyelography**

Fluoroscopic antegrade pyelography allows further evaluation of the renal transplant collecting system. There is no current literature specific to the use of fluoroscopic antegrade pyelography in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **Image-Guided Biopsy Kidney**

There is no current literature specific to the use of an image-guided renal transplant biopsy in a renal transplant with suspicion of an extrinsic etiology.

### **MAG3 Renal Scan**

There is no current literature specific to the use of MAG3 renal scan in the evaluation of a renal transplant with suspicion of an extrinsic etiology. Scintigraphy may be helpful in differentiating a urinoma from other perinephric collections such as a lymphocele or hematoma.

### **MRA Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRA abdomen and pelvis without and with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **MRA Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of MRA abdomen and pelvis without IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **MRA Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRA pelvis without and with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **MRA Pelvis Without IV Contrast**

There is no current literature specific to the use of MRA pelvis without IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **MRI Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRI abdomen and pelvis without and with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology. The modality may be useful in differentiation of peritransplant fluid collections and evaluation for posttransplant lymphoproliferative disorder. The abdominal component is of limited additional benefit.

### **MRI Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of MRI abdomen and pelvis without IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology. The modality may be useful in differentiation of peritransplant fluid collections. The abdominal component is of limited additional benefit.

### **MRI Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRI pelvis without and with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology. The modality may be useful in differentiation of peritransplant fluid collections and evaluation for posttransplant lymphoproliferative disorder.

### **MRI Pelvis Without IV Contrast**

There is no current literature specific to the use of MRI pelvis without IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology. The modality may be useful in differentiation of peritransplant fluid collections and evaluation for posttransplant lymphoproliferative disorder.

### **MRU Without and With IV Contrast**

The addition of MRU sequences allows further evaluation of the renal transplant collecting system. With IV contrast, the excretory phase permits the anatomic and functional assessment of urologic complications. Excretion of contrast into a perinephric collection confirms a urinoma. A small study by Cohnen et al [73] reported a sensitivity of 100% and a specificity of 78% in the evaluation of posttransplant urological complications. There is no current literature specific to the use of MRU without and with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **MRU Without IV Contrast**

The addition of MRU sequences allows further evaluation of the renal transplant collecting system. Without the administration of contrast to allow acquisition of excretory imaging, functional status of the transplant cannot be assessed. In a small study by Blondin et al [74], the T2-weighted MRU sequence yielded a slightly lower though not statistically significant sensitivity (76.2%) and specificity (73.7%) in the diagnosis of ureteric complications when compared to the contrast-enhanced sequences (85.7% and 83.3%, respectively). Nevertheless, there is no current literature specific to the use of MRU without IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **MRV Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRV abdomen and pelvis without and with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **MRV Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRV pelvis without and with IV contrast in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **US Duplex Doppler Kidney Transplant**

There is no current literature specific to the use of repeat duplex Doppler kidney transplant US in the evaluation of a renal transplant with suspicion of an extrinsic etiology. It is usually not useful to repeat this study, assuming that the initial US was appropriate in quality and technique. Under these circumstances, US should not be repeated.

### **US Pelvis**

There is no current literature specific to the use of a US pelvis in the initial evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **US Pelvis With IV Contrast**

CEUS is helpful in the detection of perirenal hematoma in the early postoperative period when the hematoma could appear isoechoic to adjacent renal parenchyma. Grzelak et al [75] reported a 2-fold increase in the detection of perirenal hematoma compared to a conventional renal transplant US. If there is active bleeding, contrast can be seen filling extending into the hematoma [11]. CEUS is not helpful in the differentiation between seromas, lymphoceles, or urinomas because all three will appear anechoic without enhancement.

There is no current literature specific to the use of CEUS pelvis in the in the evaluation of a renal transplant with suspicion of an extrinsic etiology.

### **Variant 5: Adult. Renal transplant dysfunction. US unremarkable or indeterminate. Next imaging study.**

This variant assumes that the initial US was performed with sufficient technology, appropriate technique, and that the images were interpreted by experts. In this setting, intrinsic dysfunction is suspected because the etiology is unlikely to be vascular in nature or extrinsic.

### **Arteriography Kidney**

There is no current literature specific to the use of arteriography of the kidney contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CT Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CT Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of CT of the abdomen and pelvis without and with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CT Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of noncontrast CT of the abdomen and pelvis without IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CT Pelvis With IV Contrast**

There is no current literature specific to the use of CT of the pelvis with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CT Pelvis Without and With IV Contrast**

There is no current literature specific to the use of CT of the pelvis without and with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CT Pelvis Without IV Contrast**

There is no current literature specific to the use of CT of the pelvis without IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CTA Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CTA of the abdomen and pelvis with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CTA Pelvis With IV Contrast**

There is no current literature specific to the use of CTA of the pelvis with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CTU Without and With IV Contrast**

There is no current literature specific to the use of CTU without and with IV contrast of the pelvis in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CTV Abdomen and Pelvis With IV Contrast**

There is no current literature specific to the use of CTV of the abdomen and pelvis with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **CTV Pelvis With IV Contrast**

There is no current literature specific to the use of CTV of the pelvis with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **DTPA Renal Scan**

There is no current literature specific to the use of DTPA renal scan in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **Fluoroscopy Antegrade Pyelography**

Fluoroscopic antegrade pyelography allows further evaluation of the renal transplant collecting system. There is no current literature specific to the use of fluoroscopic antegrade pyelography in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **Image-Guided Biopsy Kidney**

Acute rejection cannot be distinguished from other causes of renal dysfunction such as ATN or calcineurin inhibitor toxicity by imaging. Therefore, biopsy of the renal cortex with pathologic classification using the Banff criteria is highly beneficial in the evaluation of allograft dysfunction following renal transplant [76]. In a prospective study by Pascual et al [77], biopsy results altered management in approximately 40% of patients in whom a presumptive diagnosis had been made on the basis of clinical and laboratory findings. The reported complication rate is extremely low, between 0.4% and 1.0% [78,79]. The EAU guidelines provide a strong recommendation rating to perform a renal biopsy in patients with suspected acute rejection [18].

### **MAG3 Renal Scan**

There is no current literature specific to the use of MAG3 renal scan in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRA Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRA abdomen and pelvis without and with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRA Abdomen and Pelvis Without IV Contrast**

There is no current literature specific to the use of MRA abdomen and pelvis without IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRA Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRA pelvis without and with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRA Pelvis Without IV Contrast**

There is no current literature specific to the use of MRA pelvis without IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRI Abdomen and Pelvis Without and With IV Contrast**

MRI is typically used to confirm or further evaluate findings identified on renal US. The higher spatial resolution allows increased detection and characterization of focal or diffuse parenchyma abnormalities. Because the renal transplant is most frequently located in the iliac fossae, complications are most likely to be identified in the pelvis, and additional coverage of the abdomen is of little added benefit. There is no current literature specific to the use of MRI of the abdomen and pelvis without and with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRI Abdomen and Pelvis Without IV Contrast**

MRI is typically used to confirm or further evaluate findings identified on renal US. The higher spatial resolution allows increased detection and characterization of focal or diffuse parenchyma abnormalities. Because the renal transplant is most frequently located in the iliac fossae, complications are most likely to be identified in the pelvis, and additional coverage of the abdomen is of little added benefit. There is no current literature specific to the use of MRI of the abdomen and pelvis without IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRI Pelvis Without and With IV Contrast**

MRI is typically used to confirm or further evaluate findings identified on renal US. The higher spatial resolution allows increased detection and characterization of focal or diffuse parenchyma abnormalities. There is no current literature specific to the use of MRI pelvis without and with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRI Pelvis Without IV Contrast**

MRI is typically used to confirm or further evaluate findings identified on renal US. The higher spatial resolution allows increased detection and characterization of focal or diffuse parenchyma abnormalities. The administration of contrast may allow further assessment of renal masses. There is no current literature specific to the use of MRI pelvis without IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.



### **MRU Without and With IV Contrast**

There is no current literature specific to the use of MRU without and with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRU Without IV Contrast**

There is no current literature specific to the use of MRU without IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRV Abdomen and Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRV abdomen and pelvis without and with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **MRV Pelvis Without and With IV Contrast**

There is no current literature specific to the use of MRV pelvis without and with IV contrast in the evaluation of a renal transplant following an unremarkable or indeterminate US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **US Duplex Doppler Kidney Transplant**

There is no current literature specific to the use of repeat duplex Doppler kidney transplant US in the evaluation of a renal transplant following an unremarkable or indeterminate initial US. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **US Pelvis**

There is no current literature specific to the use of a US pelvis in the initial evaluation of a renal transplant with suspicion following an unremarkable or indeterminate renal transplant US because this examination does not include evaluation of the renal transplant. This imaging is not beneficial when the initial US does not demonstrate any abnormalities.

### **US Pelvis With IV Contrast**

Various indices on CEUS have shown promise in differentiating acute rejection from ATN [80-82], but these works require further validation. Like in native kidneys [83], pyelonephritis is more conspicuous on CEUS. The technique is useful in evaluation of resolution after treatment or development of renal abscess formation. CEUS can also be used to characterize and monitor complex cystic renal masses [12].

There is no current literature specific to the use of a CEUS pelvis in the evaluation of a renal transplant following an unremarkable or indeterminate US. The European Federation of Societies in Medicine and Biology recommends using CEUS as extension to conventional US to evaluate vascular complications, renal lesions, and inflammatory complications [84].

### **Summary of Highlights**

This is a summary of the key recommendations from the variant tables. Refer to the complete narrative document for more information.

- **Variant 1:** US duplex Doppler kidney transplant is usually appropriate for the initial imaging in an adult patient with renal transplant dysfunction.
- **Variant 2:** MRA abdomen and pelvis without and with IV contrast, MRA pelvis without and with IV contrast, CTA abdomen and pelvis with IV contrast, or CTA pelvis with IV contrast are usually appropriate alternative next imaging studies in patients who had a US suspicious for, but not conclusive for, arterial etiology. US pelvis with IV contrast may also be appropriate in centers that have an appropriate level of expertise. The panel did not agree on recommending arteriography kidney in this scenario. There is insufficient medical literature to conclude whether or not these patients would benefit from using this invasive modality in this scenario. Next imaging with this in this patient population is controversial but may be appropriate, especially in patients who are likely to require intervention.
- **Variant 3:** MRV abdomen and pelvis without and with IV contrast, MRV pelvis without and with IV contrast, CTV abdomen and pelvis with IV contrast, or CTV pelvis with IV contrast are usually appropriate alternative

next imaging studies in patients who had a US suspicious for, but not conclusive for, venous etiology. The panel did not agree on recommending US pelvis with IV contrast in this scenario. The usefulness of CEUS to identify and define extent of the thrombus and demonstrate areas of parenchymal ischemia or infarct has been described but has not been validated in the literature. Next imaging with this in this patient population is controversial but may be appropriate.

- **Variant 4:** MRI abdomen and pelvis without and with IV contrast, MRI abdomen and pelvis without IV contrast, MRI pelvis without and with IV contrast, MRI pelvis without IV contrast, MRU without and with IV contrast, MRU without IV contrast, CT abdomen and pelvis with IV contrast, CT abdomen and pelvis without IV contrast, CT pelvis with IV contrast, CT pelvis without IV contrast, CT abdomen and pelvis without and with IV contrast, or CTU without and with IV contrast may be appropriate as alternative next imaging studies in an adult patient with renal transplant dysfunction that had a US suspicious for, but not conclusive for, an extrinsic etiology. The panel did not agree on recommending CT pelvis without and with IV contrast in this scenario. There is insufficient medical literature to conclude whether or not these patients would benefit from using this modality in this scenario. Next imaging in this patient population is controversial but may be appropriate.
- **Variant 5:** Image-guided biopsy kidney is usually appropriate as a next imaging study in an adult patient with renal transplant dysfunction with an initial US that is unremarkable or indeterminate. These patients are presumed to have intrinsic dysfunction as the suspected etiology with the etiology unlikely to be vascular or extrinsic in nature.

### 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 go to [www.acr.org/ac](http://www.acr.org/ac).

### Gender Equality and Inclusivity Clause

The ACR acknowledges the limitations in applying inclusive language when citing research studies that pre-dates the use of the current understanding of language inclusive of diversity in sex, intersex, gender and gender-diverse people. The data variables regarding sex and gender used in the cited literature will not be changed. However, this guideline will use the terminology and definitions as proposed by the National Institutes of Health [85].

## 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 [86].

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

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

## References

1. Elsayes KM, Menias CO, Willatt J, Azar S, Harvin HJ, Platt JF. Imaging of renal transplant: utility and spectrum of diagnostic findings. *Curr Probl Diagn Radiol* 2011;40:127-39.

2. OPTN/SRTR: Transplant Data. Available at: <https://optn.transplant.hrsa.gov/data/view-data-reports/national-data/#>. Accessed September 30, 2024.
3. Dubovsky EV, Russell CD, Erbas B. Radionuclide evaluation of renal transplants. *Semin Nucl Med* 1995;25:49-59.
4. Sharfuddin A. Imaging evaluation of kidney transplant recipients. *Semin Nephrol* 2011;31:259-71.
5. Zarzour JG, Lockhart ME. Ultrasonography of the Renal Transplant. *Ultrasound Clinics* 2014;9:683-95.
6. Dimitroulis D, Bokos J, Zavos G, et al. Vascular complications in renal transplantation: a single-center experience in 1367 renal transplantations and review of the literature. *Transplant Proc* 2009;41:1609-14.
7. Eufrazio P, Parada B, Moreira P, et al. Surgical complications in 2000 renal transplants. *Transplant Proc* 2011;43:142-4.
8. Akbar SA, Jafri SZ, Amendola MA, Madrazo BL, Salem R, Bis KG. Complications of renal transplantation. *Radiographics* 2005;25:1335-56.
9. Sharfuddin A. Renal relevant radiology: imaging in kidney transplantation. *Clin J Am Soc Nephrol* 2014;9:416-29.
10. Smith AD, Nikolaidis P, Khatri G, et al. ACR Appropriateness Criteria® Acute Pyelonephritis: 2022 Update. *J Am Coll Radiol* 2022;19:S224-S39.
11. Kazmierski BJ, Sharbidre KG, Robbin ML, Grant EG. Contrast-Enhanced Ultrasound for the Evaluation of Renal Transplants. *J Ultrasound Med* 2020;39:2457-68.
12. Morgan TA, Jha P, Poder L, Weinstein S. Advanced ultrasound applications in the assessment of renal transplants: contrast-enhanced ultrasound, elastography, and B-flow. *Abdom Radiol (NY)* 2018;43:2604-14.
13. Heaf JG, Iversen J. Uses and limitations of renal scintigraphy in renal transplantation monitoring. *Eur J Nucl Med* 2000;27:871-9.
14. Yazici B, Yazici A, Oral A, Akgun A, Toz H. Comparison of renal transplant scintigraphy with renal resistance index for prediction of early graft dysfunction and evaluation of acute tubular necrosis and acute rejection. *Clin Nucl Med* 2013;38:931-5.
15. Aktas A, Aras M, Colak T, Gencoglu A, Karakayali H. Comparison of Tc-99m DTPA and Tc-99m MAG3 perfusion time-activity curves in patients with renal allograft dysfunction. *Transplant Proc* 2006;38:449-53.
16. Lubin E, Shapira Z, Melloul M, Youssim A. Scintigraphic detection of vascular and urological complications in the transplanted kidney: 133 cases. *Eur J Nucl Med* 1985;10:313-6.
17. Zavos G, Pappas P, Karatzas T, et al. Urological complications: analysis and management of 1525 consecutive renal transplantations. *Transplant Proc* 2008;40:1386-90.
18. Rodriguez Faba O, Boissier R, Budde K, et al. European Association of Urology Guidelines on Renal Transplantation: Update 2018. *Eur Urol Focus* 2018;4:208-15.
19. Lee SF, Lichtenstein M, Hughes P, Sivaratnam D. Utility of MAG3 scintigraphy with the use of a 2 min uptake parameter in the assessment of postsurgical renal transplant complications. *Nucl Med Commun* 2018;39:921-27.
20. Aktas A. Transplanted kidney function evaluation. *Semin Nucl Med* 2014;44:129-45.
21. Nankivell BJ, Cohn DA, Spicer ST, Evans SG, Chapman JR, Gruenewald SM. Diagnosis of kidney transplant obstruction using Mag3 diuretic renography. *Clin Transplant* 2001;15:11-8.
22. Buckley AR, Cooperberg PL, Reeve CE, Magil AB. The distinction between acute renal transplant rejection and cyclosporine nephrotoxicity: value of duplex sonography. *AJR Am J Roentgenol* 1987;149:521-5.
23. Steinberg HV, Nelson RC, Murphy FB, et al. Renal allograft rejection: evaluation by Doppler US and MR imaging. *Radiology* 1987;162:337-42.
24. Jenkins SM, Sanfilippo FP, Carroll BA. Duplex Doppler sonography of renal transplants: lack of sensitivity and specificity in establishing pathologic diagnosis. *AJR Am J Roentgenol* 1989;152:535-9.
25. Rifkin MD, Needleman L, Pasto ME, et al. Evaluation of renal transplant rejection by duplex Doppler examination: value of the resistive index. *AJR Am J Roentgenol* 1987;148:759-62.
26. Radermacher J, Mengel M, Ellis S, et al. The renal arterial resistance index and renal allograft survival. *N Engl J Med* 2003;349:115-24.
27. McArthur C, Geddes CC, Baxter GM. Early measurement of pulsatility and resistive indexes: correlation with long-term renal transplant function. *Radiology* 2011;259:278-85.
28. Naesens M, Heylen L, Lerut E, et al. Intrarenal resistive index after renal transplantation. *N Engl J Med* 2013;369:1797-806.
29. Baxter GM, Ireland H, Moss JG, et al. Colour Doppler ultrasound in renal transplant artery stenosis: which Doppler index? *Clin Radiol* 1995;50:618-22.

30. Krumme B, Grotz W, Kirste G, Schollmeyer P, Rump LC. Determinants of intrarenal Doppler indices in stable renal allografts. *J Am Soc Nephrol* 1997;8:813-6.
31. Patel U, Khaw KK, Hughes NC. Doppler ultrasound for detection of renal transplant artery stenosis-threshold peak systolic velocity needs to be higher in a low-risk or surveillance population. *Clin Radiol* 2003;58:772-7.
32. de Moraes RH, Muglia VF, Mamere AE, et al. Duplex Doppler sonography of transplant renal artery stenosis. *J Clin Ultrasound* 2003;31:135-41.
33. AbuRahma AF, Srivastava M, Mousa AY, et al. Critical analysis of renal duplex ultrasound parameters in detecting significant renal artery stenosis. *J Vasc Surg* 2012;56:1052-9, 60 e1; discussion 59-60.
34. Fananapazir G, McGahan JP, Corwin MT, et al. Screening for Transplant Renal Artery Stenosis: Ultrasound-Based Stenosis Probability Stratification. *AJR Am J Roentgenol* 2017;209:1064-73.
35. Baxter GM. Imaging in renal transplantation. *Ultrasound Q* 2003;19:123-38.
36. Baxter GM, Morley P, Dall B. Acute renal vein thrombosis in renal allografts: new Doppler ultrasonic findings. *Clin Radiol* 1991;43:125-7.
37. Lockhart ME, Wells CG, Morgan DE, Fineberg NS, Robbin ML. Reversed diastolic flow in the renal transplant: perioperative implications versus transplants older than 1 month. *AJR Am J Roentgenol* 2008;190:650-5.
38. Glebova NO, Brooke BS, Desai NM, Lum YW. Endovascular interventions for managing vascular complication of renal transplantation. *Semin Vasc Surg* 2013;26:205-12.
39. Marini M, Fernandez-Rivera C, Cao I, et al. Treatment of transplant renal artery stenosis by percutaneous transluminal angioplasty and/or stenting: study in 63 patients in a single institution. *Transplant Proc* 2011;43:2205-7.
40. Sharma S, Potdar A, Kulkarni A. Percutaneous transluminal renal stenting for transplant renal artery stenosis. *Catheter Cardiovasc Interv* 2011;77:287-93.
41. Audard V, Matignon M, Hemery F, et al. Risk factors and long-term outcome of transplant renal artery stenosis in adult recipients after treatment by percutaneous transluminal angioplasty. *Am J Transplant* 2006;6:95-9.
42. Beecroft JR, Rajan DK, Clark TW, Robinette M, Stavropoulos SW. Transplant renal artery stenosis: outcome after percutaneous intervention. *J Vasc Interv Radiol* 2004;15:1407-13.
43. Geddes CC, McManus SK, Koteeswaran S, Baxter GM. Long-term outcome of transplant renal artery stenosis managed conservatively or by radiological intervention. *Clin Transplant* 2008;22:572-8.
44. Ghazanfar A, Tavakoli A, Augustine T, Pararajasingam R, Riad H, Chalmers N. Management of transplant renal artery stenosis and its impact on long-term allograft survival: a single-centre experience. *Nephrol Dial Transplant* 2011;26:336-43.
45. Hagen G, Wadstrom J, Magnusson M, Magnusson A. Outcome after percutaneous transluminal angioplasty of arterial stenosis in renal transplant patients. *Acta Radiol* 2009;50:270-5.
46. Henning BF, Kuchlbauer S, Boger CA, et al. Percutaneous transluminal angioplasty as first-line treatment of transplant renal artery stenosis. *Clin Nephrol* 2009;71:543-9.
47. Pappas P, Zavos G, Kaza S, et al. Angioplasty and stenting of arterial stenosis affecting renal transplant function. *Transplant Proc* 2008;40:1391-6.
48. Peregrin JH, Stribna J, Lacha J, Skibova J. Long-term follow-up of renal transplant patients with renal artery stenosis treated by percutaneous angioplasty. *Eur J Radiol* 2008;66:512-8.
49. Polak WG, Jezior D, Garczarek J, et al. Incidence and outcome of transplant renal artery stenosis: single center experience. *Transplant Proc* 2006;38:131-2.
50. Seratnaehai A, Shah A, Bodiwala K, Mukherjee D. Management of transplant renal artery stenosis. *Angiology* 2011;62:219-24.
51. Valpreda S, Messina M, Rabbia C. Stenting of transplant renal artery stenosis: outcome in a single center study. *J Cardiovasc Surg (Torino)* 2008;49:565-70.
52. Voiculescu A, Schmitz M, Hollenbeck M, et al. Management of arterial stenosis affecting kidney graft perfusion: a single-centre study in 53 patients. *Am J Transplant* 2005;5:1731-8.
53. Laberge JM. Interventional management of renal transplant arteriovenous fistula. *Semin Intervent Radiol* 2004;21:239-46.
54. Nicolini A, Ferraresso M, Lovaria A, Biondetti P, Raiteri M, Berardinelli L. Carbon dioxide as a valuable contrast agent for identifying iatrogenic arteriovenous fistulas in transplanted kidneys. *Nephrol Dial Transplant* 2003;18:2189-92.
55. Rountas C, Vlychou M, Vassiou K, et al. Imaging modalities for renal artery stenosis in suspected renovascular hypertension: prospective intraindividual comparison of color Doppler US, CT angiography, GD-enhanced MR angiography, and digital subtraction angiography. *Ren Fail* 2007;29:295-302.

56. Helck A, Bamberg F, Sommer WH, et al. Optimized contrast volume for dynamic CT angiography in renal transplant patients using a multiphase CT protocol. *Eur J Radiol* 2011;80:692-8.
57. Gaddikeri S, Mitsumori L, Vaidya S, Hippe DS, Bhargava P, Dighe MK. Comparing the diagnostic accuracy of contrast-enhanced computed tomographic angiography and gadolinium-enhanced magnetic resonance angiography for the assessment of hemodynamically significant transplant renal artery stenosis. *Curr Probl Diagn Radiol* 2014;43:162-8.
58. Mousa D, Hamilton D, Miola UJ, et al. The importance of the perfusion index in the evaluation of captopril renography for transplant renal artery stenosis. *Nucl Med Commun* 1994;15:949-52.
59. Erbas B. Peri- and Postsurgical Evaluations of Renal Transplant. *Semin Nucl Med* 2017;47:647-59.
60. Omary RA, Baden JG, Becker BN, Odorico JS, Grist TM. Impact of MR angiography on the diagnosis and management of renal transplant dysfunction. *J Vasc Interv Radiol* 2000;11:991-6.
61. Sharafuddin MJ, Stolpen AH, Dixon BS, Andresen KJ, Sun S, Lawton WJ. Value of MR angiography before percutaneous transluminal renal artery angioplasty and stent placement. *J Vasc Interv Radiol* 2002;13:901-8.
62. Neimatallah MA, Dong Q, Schoenberg SO, Cho KJ, Prince MR. Magnetic resonance imaging in renal transplantation. *J Magn Reson Imaging* 1999;10:357-68.
63. Ismaeel MM, Abdel-Hamid A. Role of high resolution contrast-enhanced magnetic resonance angiography (HR CeMRA) in management of arterial complications of the renal transplant. *Eur J Radiol* 2011;79:e122-7.
64. Liu X, Berg N, Sheehan J, et al. Renal transplant: nonenhanced renal MR angiography with magnetization-prepared steady-state free precession. *Radiology* 2009;251:535-42.
65. Lanzman RS, Voiculescu A, Walther C, et al. ECG-gated nonenhanced 3D steady-state free precession MR angiography in assessment of transplant renal arteries: comparison with DSA. *Radiology* 2009;252:914-21.
66. Bultman EM, Klaers J, Johnson KM, et al. Non-contrast enhanced 3D SSFP MRA of the renal allograft vasculature: a comparison between radial linear combination and Cartesian inflow-weighted acquisitions. *Magn Reson Imaging* 2014;32:190-5.
67. Tang H, Wang Z, Wang L, et al. Depiction of transplant renal vascular anatomy and complications: unenhanced MR angiography by using spatial labeling with multiple inversion pulses. *Radiology* 2014;271:879-87.
68. Zhang LJ, Peng J, Wen J, et al. Non-contrast-enhanced magnetic resonance angiography: a reliable clinical tool for evaluating transplant renal artery stenosis. *Eur Radiol* 2018;28:4195-204.
69. Pan FS, Liu M, Luo J, et al. Transplant renal artery stenosis: Evaluation with contrast-enhanced ultrasound. *Eur J Radiol* 2017;90:42-49.
70. Advances in Biomedical Alcohol Research. Proceedings of the 5th ISBRA/RSA Congress. Toronto, Canada, 17-22 June 1990. *Alcohol Alcohol Suppl* 1991;1:1-534.
71. Kim HS, Fine DM, Atta MG. Catheter-directed thrombectomy and thrombolysis for acute renal vein thrombosis. *J Vasc Interv Radiol* 2006;17:815-22.
72. Sciascia N, Zompatori M, Di Scioscio V, et al. Multidetector CT-urography in the study of urological complications in renal transplant. *Radiol Med* 2002;103:501-10.
73. Cohnen M, Brause M, May P, et al. Contrast-enhanced MR urography in the evaluation of renal transplants with urological complications. *Clin Nephrol* 2002;58:111-7.
74. Blondin D, Koester A, Andersen K, Kurz KD, Moedder U, Cohnen M. Renal transplant failure due to urologic complications: Comparison of static fluid with contrast-enhanced magnetic resonance urography. *Eur J Radiol* 2009;69:324-30.
75. Grzelak P, Kurnatowska I, Nowicki M, et al. The diagnostic value of contrast-enhanced ultrasonography in the assessment of perirenal hematomas in the early post-operative period after kidney transplantation. *Clin Transplant* 2013;27:E619-24.
76. Williams WW, Taheri D, Tolkoff-Rubin N, Colvin RB. Clinical role of the renal transplant biopsy. *Nat Rev Nephrol* 2012;8:110-21.
77. Pascual M, Vallhonrat H, Cosimi AB, et al. The clinical usefulness of the renal allograft biopsy in the cyclosporine era: a prospective study. *Transplantation* 1999;67:737-41.
78. Schwarz A, Gwinner W, Hiss M, Radermacher J, Mengel M, Haller H. Safety and adequacy of renal transplant protocol biopsies. *Am J Transplant* 2005;5:1992-6.
79. Furness PN, Philpott CM, Chorbajian MT, et al. Protocol biopsy of the stable renal transplant: a multicenter study of methods and complication rates. *Transplantation* 2003;76:969-73.
80. Benozzi L, Cappelli G, Granito M, et al. Contrast-enhanced sonography in early kidney graft dysfunction. *Transplant Proc* 2009;41:1214-5.

81. Goyal A, Hemachandran N, Kumar A, et al. Evaluation of the Graft Kidney in the Early Postoperative Period: Performance of Contrast-Enhanced Ultrasound and Additional Ultrasound Parameters. *J Ultrasound Med* 2021;40:1771-83.
82. Zhou Q, Yu Y, Qin W, et al. Current Status of Ultrasound in Acute Rejection After Renal Transplantation: A Review with a Focus on Contrast-Enhanced Ultrasound. *Ann Transplant* 2021;26:e929729.
83. Fontanilla T, Minaya J, Cortes C, et al. Acute complicated pyelonephritis: contrast-enhanced ultrasound. *Abdom Imaging* 2012;37:639-46.
84. Mueller-Peltzer K, Rubenthaler J, Fischereder M, Habicht A, Reiser M, Clevert DA. The diagnostic value of contrast-enhanced ultrasound (CEUS) as a new technique for imaging of vascular complications in renal transplants compared to standard imaging modalities. *Clin Hemorheol Microcirc* 2017;67:407-13.
85. National Academies of Sciences, Engineering, and Medicine; Division of Behavioral and Social Sciences and Education; Committee on National Statistics; Committee on Measuring Sex, Gender Identity, and Sexual Orientation. *Measuring Sex, Gender Identity, and Sexual Orientation*. In: Becker T, Chin M, Bates N, eds. *Measuring Sex, Gender Identity, and Sexual Orientation*. Washington (DC): National Academies Press (US) Copyright 2022 by the National Academy of Sciences. All rights reserved.; 2022.
86. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf>. Accessed September 30, 2024.

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.