Radiologic assessment of renal disease

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INTRODUCTION

A large number of radiologic studies are used to evaluate patients with renal disease. These tests are performed alone or in combination for the detection, diagnosis, and/or the evaluation of multiple conditions. They are most often used to assess urinary tract obstruction, kidney stones, renal cyst or mass, kidney size, disorders with characteristic radiographic findings, renal vascular diseases, and vesicoureteral reflux (VUR).

The more commonly used imaging studies include:

- Ultrasonography
- Computed tomography (CT)
- Magnetic resonance imaging (MRI)
- Plain film of the abdomen
- Intravenous urogram
- Renal arteriography
- Renal venography
- Voiding cystourethrography (VCUG)
- Radionuclide studies
- Retrograde or anterograde pyelography

Because of safety, ease of use, and the information provided, the most commonly used radiographic technique in patients presenting with renal disease is renal ultrasonography. Since obstruction is a readily reversible disorder, **all** patients presenting with renal failure of unknown etiology should undergo ultrasonography, the modality of choice to detect possible obstructive disease. (See "Clinical manifestations and diagnosis of urinary tract obstruction and hydronephrosis", section on 'Diagnosis'.)

The following is a brief introduction to the use of radiologic studies in the evaluation of patients with a variety of suspected or confirmed renal disorders. Detailed discussions concerning the findings and optimal use of these modalities, as well as other techniques, are presented separately in topics reviewing individual diseases for which these modalities are routinely employed.

RADIOLOGIC STUDIES

Ultrasonography — Renal ultrasonography is the test of choice to exclude urinary tract obstruction since it allows one to avoid the potential allergic and toxic complications of radiocontrast media (image 1 and image 2) [1]. Ultrasound can, in the majority of affected patients, diagnose hydronephrosis and often establish its cause. Since urinary tract obstruction is easily diagnosed and reversible when treated early, ultrasonography should be performed in **all** patients presenting with renal failure of unknown etiology. (See "Clinical manifestations and diagnosis of urinary tract obstruction and hydronephrosis".)

While ultrasound is useful for detecting proximal obstruction of the ureter (image 3), it is less sensitive for showing the level and cause of obstruction when obstruction is in the lower abdomen or pelvis, especially when the ureter is obscured by overlying bowel. One exception is when a stone is impacted at the ureterovesical junction; when this is suspected, a pelvic ultrasound examination may be useful. The bladder should be examined in all cases of hydronephrosis, whether or not the proximal ureter is dilated.

Although less sensitive than computed tomography (CT) in initially detecting a renal mass, ultrasonography can be useful in differentiating a simple, benign renal cyst from a more complex cyst or a solid tumor [2,3] (see "Simple and complex kidney cysts in adults"). It is also commonly used to screen for and diagnose polycystic kidney disease. (See "Autosomal dominant polycystic kidney disease (ADPKD) in adults: Epidemiology, clinical presentation, and diagnosis", section on 'Diagnosis'.)

Ultrasonography or CT scanning should also be considered in patients with pyelonephritis who continue to have an incomplete response to antimicrobial therapy. These techniques can rule out the presence of obstruction, renal or perinephric abscesses, and other complications of pyelonephritis (image 4). CT scanning with contrast may be required to identify abscesses. (See "Acute complicated urinary tract infection (including pyelonephritis) in adults", section on 'Imaging'.)

Findings on ultrasonography are also frequently utilized to assess the presence of irreversible kidney disease, based upon kidney size and cortical thickness. Increased echogenicity is a nonspecific finding seen with many diffuse renal diseases that does **not** necessarily indicate irreversible disease. In contrast, the combination of increased echogenicity and kidney length <10 cm almost always indicates untreatable disease [4]. Although the resistive index is often used as a marker of renal parenchymal disease, it is a nonspecific parameter. However, it can be useful in the evaluation of renal artery stenosis [5,6]. Ultrasound is also useful in diagnosing nephrocalcinosis, which can be caused by various etiologies like medullary cystic disease, renal tubular acidosis, and hyperparathyroidism [7,8]; however, it cannot be used to reliably exclude the presence of small, nonobstructing stones.

Doppler ultrasonography — Doppler ultrasonography can be used to evaluate renal vascular flow in multiple disorders. These include evaluation of renal artery stenosis, renal vein thrombosis, and renal infarction. However, CT and magnetic resonance (MR) are more sensitive for these conditions and are usually required for confirmation. Doppler ultrasonography to screen for renal artery stenosis is a technically challenging study [9] and is only reliable in high-volume centers when performed and interpreted by experienced radiologists. (See "Establishing the diagnosis of renovascular hypertension", section on 'Duplex Doppler ultrasonography'.)

Doppler ultrasonography is also used to obtain the renal resistive index, which is calculated from the following formula:

(Peak systolic velocity - end diastolic velocity) ÷ Peak systolic velocity

The normal renal resistive index is <0.7. A high renal resistive index can be observed in a wide variety of disorders and is dependent primarily on extrarenal hemodynamics rather than intrarenal factors [5,10]. As a result, the renal resistive index is of **no** utility in the diagnosis of renal parenchymal disease. Resistive index is commonly measured in transplanted kidneys but is an insensitive and nonspecific indicator of rejection [6,11,12]. While the resistive index has prognostic value, this is probably related to systemic factors rather than renal abnormalities [6].

Computed tomography — CT often provides complementary information to that obtained with renal ultrasonography. In particular, CT with contrast is used to evaluate complex renal cysts and possible masses detected by ultrasonography [13]. Conversely, renal ultrasonography can often clarify whether indeterminant masses on CT scanning are cystic. (See "Simple and complex kidney cysts in adults".)

There are several other indications for CT in patients with renal disease:

- Noncontrast low-radiation dose CT scan is the gold standard for the radiologic diagnosis of renal stone disease (image 5A-B), including the detection of small stones or ureteral stones not detectable by ultrasound or stones not visualized on plain films of the abdomen, and is the appropriate initial imaging test for suspected renal colic. (See "Kidney stones in adults: Diagnosis and acute management of suspected nephrolithiasis", section on 'Noncontrast CT'.)

- CT is used for confirmation and localization of ureteral obstruction that is suspected, but not visible, by ultrasonography.

- Autosomal dominant polycystic kidney disease can be diagnosed with CT scanning with a higher sensitivity than that obtained with renal ultrasonography, particularly in younger patients. However, ultrasonography is usually the preferred initial screening test, and CT scanning is rarely required. (See "Autosomal dominant polycystic kidney disease (ADPKD) in adults: Epidemiology, clinical presentation, and diagnosis", section on 'Establishing the diagnosis of ADPKD'.)

- CT is used to evaluate and stage renal tumors and to diagnose renal vein thrombosis. (See "Clinical manifestations, evaluation, and staging of renal cell carcinoma", section on 'CT or ultrasonography' and "Renal vein thrombosis in adults", section on 'Evaluation and diagnosis'.)

Consultation with the radiologist is recommended prior to CT scanning since this can often prevent the unnecessary use of radiocontrast agents.

Magnetic resonance imaging — Magnetic resonance imaging (MRI) of the kidneys is performed in a variety of clinical settings:

- MR angiography has a role in evaluating patients with suspected renovascular hypertension and, in many patients, has reduced the need for renal angiography. However, the administration of gadolinium during MRI was strongly linked to an often severe disease called nephrogenic systemic fibrosis (NSF) among patients with reduced estimated glomerular filtration rate (eGFR), particularly those requiring dialysis. As a result, the US Food and Drug Administration (FDA) recommended that gadolinium-based imaging be avoided, if possible, in patients with an eGFR <30 mL/min/1.73 m^2. However, the risk of NSF varies considerably among the different gadolinium compounds and may be minimal with some, so prior consultation with the radiologist is advised. The use of gadolinium in patients with reduced kidney function is discussed at length elsewhere. (See "Nephrogenic systemic fibrosis/nephrogenic fibrosing dermopathy in advanced kidney disease".)

- MRI, along with renal venography and CT scanning, are considered gold standards for the diagnosis of renal vein thrombosis. (See "Renal vein thrombosis in adults", section on 'Evaluation and diagnosis'.)

- MRI is used in the evaluation of renal masses, including suspected or confirmed renal cell carcinoma. MRI is especially useful for distinguishing and characterizing complex solid and cystic masses (see "Simple and complex kidney cysts in adults", section on 'MRI for additional evaluation and active surveillance'). It may be a useful adjunct when ultrasonography and CT scanning are nondiagnostic and/or radiocontrast media cannot be administered due to allergy or to reduced kidney function, which increases the risk of contrast-induced nephropathy, particularly in patients with diabetes. (See "Clinical manifestations, evaluation, and staging of renal cell carcinoma", section on 'MRI' and "Prevention of contrast-induced acute kidney injury associated with angiography" and "Prevention of contrast-induced acute kidney injury associated with angiography", section on 'Epidemiology'.)

Abdominal radiography — Abdominal radiography (ie, plain film of the abdomen) is **not** commonly performed in patients with suspected renal disease. Among patients presenting with symptoms suggestive of nephrolithiasis, a plain film of the abdomen can identify calcium-containing, struvite, and cystine stones (image 6) but will miss radiolucent uric acid stones and may miss small radiopaque stones or stones overlying bony structures. As previously mentioned, the diagnostic test of choice when nephrolithiasis is suspected is a noncontrast low-dose CT scan. (See 'Computed tomography' above and "Kidney stones in adults: Diagnosis and acute management of suspected nephrolithiasis", section on 'Noncontrast CT'.)

Intravenous urogram — In the past, intravenous urogram (also called intravenous pyelogram [IVP]) was the principal radiologic technique used in evaluating the patient with possible renal disease. It provides detailed information concerning caliceal anatomy and the size and shape of the kidney and is useful in detecting renal stones. However, IVP is **used infrequently** since it requires the administration of contrast; is associated with substantial radiation exposure; and other techniques, such as ultrasonography and CT, frequently provide similar or more detailed information.

IVP has high sensitivity and specificity for the detection of renal stone disease and provides data on the degree of obstruction. However, noncontrast-enhanced low-dose CT scanning is the gold standard for the radiologic diagnosis of renal stone disease. (See "Kidney stones in adults: Diagnosis and acute management of suspected nephrolithiasis", section on 'Noncontrast CT'.)

Renal arteriography — Renal arteriography is used less frequently because of the availability of noninvasive tests such as CT and MR angiography. However, it remains useful in certain settings, such as the patient with suspected polyarteritis nodosa [14]. Arteriography is often diagnostic in this disorder, demonstrating multiple aneurysms and irregular constrictions in the larger vessels, with occlusion of smaller penetrating arteries (image 7). (See "Clinical manifestations and diagnosis of polyarteritis nodosa in adults", section on 'Arteriography and cross-sectional imaging'.)

Voiding cystourethrography — Voiding cystourethrography (VCUG) is primarily used to establish the presence and severity of vesicoureteral reflux (VUR) (image 8 and image 9). (See "Urinary tract infections in infants older than one month and young children: Acute management, imaging, and prognosis", section on 'Voiding cystourethrogram' and "Clinical presentation, diagnosis, and course of primary vesicoureteral reflux".)

VCUG is also used to diagnosis posterior urethral valves (image 10 and image 11) and to provide information on bladder shape and function in children with bladder dysfunction. (See "Clinical presentation and diagnosis of posterior urethral valves", section on 'Diagnosis' and "Evaluation and diagnosis of bladder dysfunction in children", section on 'Voiding cystourethrogram'.)

Radionuclide studies — Radionuclide studies include renal scans and radionuclide cystography.

Renal scans — Renal scans can provide both functional and anatomic information. Although CT can provide similar information (see 'Computed tomography' above), renal scans are the preferred imaging modality in children and infants because of the reduced radiation exposure compared with CT.

Renal scans using the radioisotope technetium Tc-99m mertiatide (Tc-99mMAG3) assess renal excretory function. It is the study of choice in differentiating between obstructive and nonobstructive hydronephrosis in infants and children and can also identify a difference in function between the two kidneys. This test may be used in adults but is rarely required. (See "Postnatal management of fetal hydronephrosis", section on 'Diuretic renography'.)

Static renal scans using the radioisotope Tc-99m succimer (DMSA) provide better visualization than Tc99mMAG3 scans of focal renal parenchymal abnormalities and better assessment of a difference in kidney function between the two kidneys (image 12). DMSA scans can also be used in children with a febrile urinary tract infection to detect acute pyelonephritis or as a follow-up test to detect focal renal scarring. (See "Urinary tract infections in infants older than one month and young children: Acute management, imaging, and prognosis", section on 'Renal scintigraphy' and "Evaluation of congenital anomalies of the kidney and urinary tract (CAKUT)", section on 'Static renal scan'.)

Radionuclide cystogram — Radionuclide cystograms (RNCs) are also used to detect VUR (picture 1). Although VCUG provides greater anatomic detail, there is increased radiation exposure with VCUG compared with RNC. As a result, RNC is often used preferentially for follow-up imaging in patients with VUR. (See "Clinical presentation, diagnosis, and course of primary vesicoureteral reflux", section on 'Diagnosis'.)

Retrograde or anterograde pyelography — Antegrade or retrograde pyelography has been used to diagnose urinary tract obstruction but has largely been supplanted by ultrasonography and CT scanning. However, pyelography may be indicated when the history is highly suggestive of urinary tract obstruction (eg, unexplained acute kidney injury [AKI] with a bland urine sediment in a patient with known pelvic malignancy) and hydronephrosis is absent on ultrasonography and CT scanning due to possible urinary tract encasement [1].

Retrograde studies can also be useful for localizing the obstruction when there is insufficient kidney function to excrete intravenous contrast.

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Chronic kidney disease in adults".)

SUMMARY

- Renal ultrasonography is the test of choice to exclude urinary tract obstruction, thereby avoiding the potential allergic and toxic complications of radiocontrast media (image 13). Although less sensitive than computed tomography (CT) for initially detecting a renal mass, ultrasonography can also be useful in differentiating a simple benign cyst from a more complex cyst or a solid tumor and in detecting complications of pyelonephritis in a patient who has an incomplete response to antimicrobial therapy (image 4). In addition, ultrasonography can identify cortical thinning and decreased kidney size, indicative of irreversible kidney disease. (See 'Ultrasonography' above.)

- Doppler renal ultrasonography can be used to evaluate renal vascular flow in multiple disorders, including renal vein thrombosis, renal infarction, and renal artery stenosis, but requires a high level of expertise. (See 'Doppler ultrasonography' above.)

- Noncontrast low-dose CT scanning is the gold standard for the radiologic diagnosis of renal stone disease (image 5A-B), including the detection of stones not visualized on plain films or sonography. In addition, CT is also used to confirm and localize ureteral obstruction and to evaluate and stage renal tumors and can be employed to diagnose renal vein thrombosis and polycystic kidney disease. (See 'Computed tomography' above.)

- Magnetic resonance imaging (MRI) of the kidneys is performed in a variety of clinical settings, including suspected renovascular hypertension, renal vein thrombosis, and in the evaluation of renal masses, including suspected or confirmed renal cell carcinoma. However, the administration of gadolinium during MRI has been linked to nephrogenic systemic fibrosis (NSF) among patients with reduced estimated glomerular filtration rate (eGFR), particularly those requiring dialysis. (See 'Magnetic resonance imaging' above.)

- A plain film of the abdomen is not commonly performed as the first study in patients with suspected renal disease, although it can identify calcium-containing, struvite, and cystine kidney stones of sufficient size (image 6). (See 'Abdominal radiography' above.)

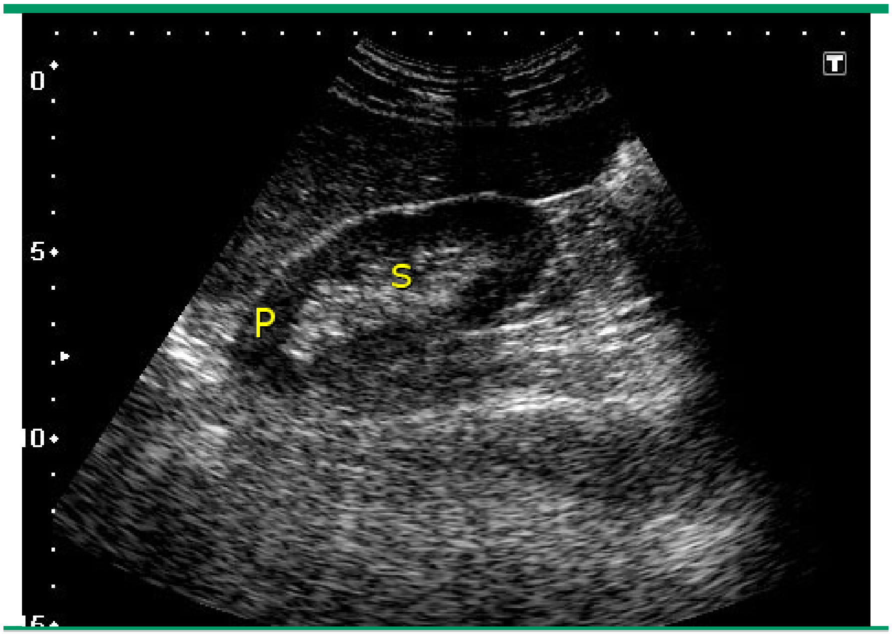
- Renal arteriography is used less frequently because of the availability of noninvasive tests such as CT scanning and MRI. However, it remains useful in certain settings, such as patients with suspected polyarteritis nodosa, since it can demonstrate aneurysms and irregular constrictions in the larger vessels with occlusion of smaller penetrating arteries (image 7). (See 'Renal arteriography' above.)

- Radionuclide scanning provides functional data and can determine the function of each kidney. Early detection of vesicoureteral reflux (VUR) and scarring is possible with radioisotope scanning with technetium Tc-99m succimer (DMSA) and a voiding cystourethrogram. DMSA scanning is more sensitive than intravenous urography in detecting renal scars and is the preferred test for many pediatric nephrologists and radiologists. (See 'Radionuclide studies' above and 'Voiding cystourethrography' above.)

Topic 7194 Version 26.0

GRAPHICS

Ultrasound of a normal kidney



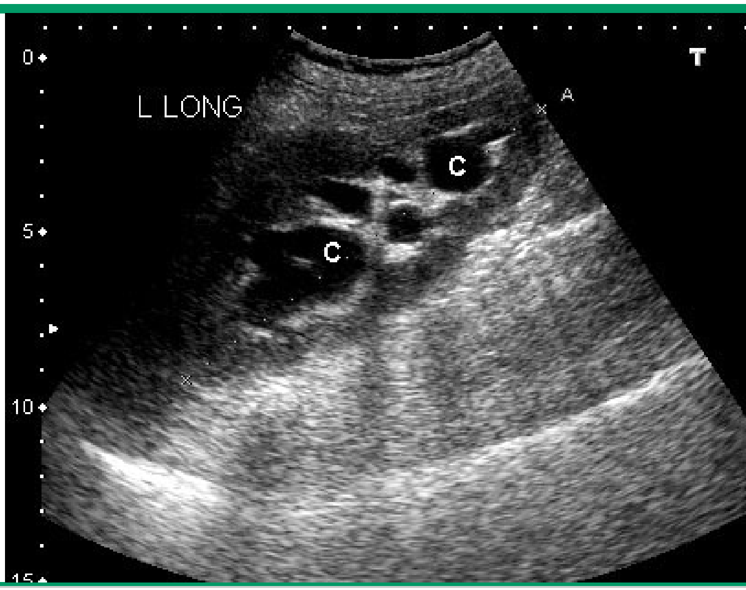
Normal kidney with a hypoechoic parenchyma (P) surrounding the echogenic renal sinus. There should be few if any fluid-filled structures with the renal sinus.

S: renal sinus.

Courtesy of W Charles O'Neill, MD.

Graphic 94099 Version 3.0

Ultrasound of a kidney with hydronephrosis

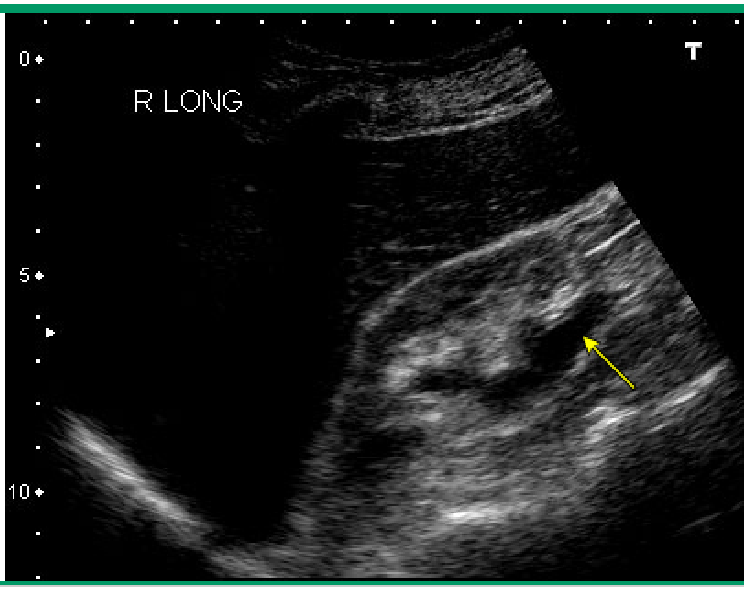


Sonogram of a kidney with hydronephrosis. Dilated calyces (C) appear as fluid-filled structures within the renal sinus.

Courtesy of W Charles O'Neill, MD.

Graphic 94100 Version 1.0

Ultrasound of a kidney with hydronephrosis and a dilated proximal ureter

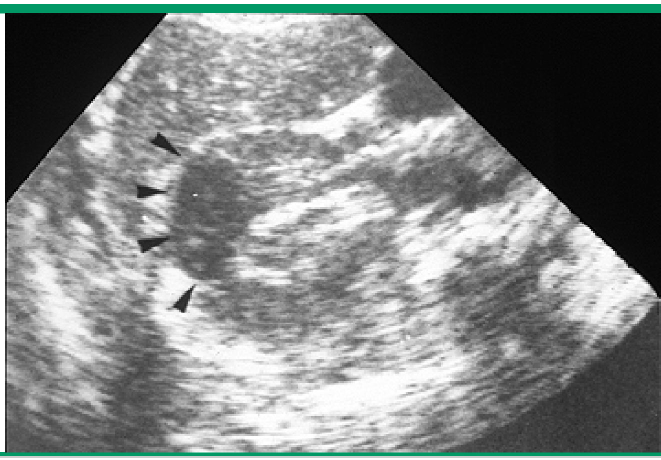


Sonogram of a kidney with hydronephrosis and a dilated proximal ureter (arrow).

Courtesy of W Charles O'Neill, MD.

Graphic 94101 Version 1.0

Ultrasonography of acute pyelonephritis



Renal ultrasonography in a patient with acute pyelonephritis showing a hypodense mass with internal echoes (outlined by the arrows).

Courtesy of Alain Meyrier, MD.

Graphic 62046 Version 4.0

CT of a ureteral stone

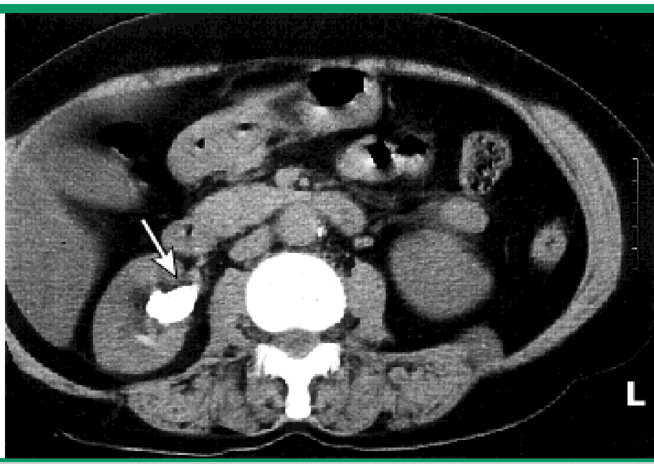
Ureterolithiasis with obstruction. Image of the abdomen from a CT with intravenous contrast shows a stone (arrow) in the proximal left ureter with slight delayed enhancement and mild hydronephrosis of the left kidney. The right kidney is normal with high density contrast excretion in the right ureter (arrowhead).

CT: computed tomography.

Courtesy of Jonathan Kruskal, MD.

Graphic 69052 Version 6.0

CT of kidney stone



Nephrolithiasis. Image of abdomen from a noncontrast CT shows a stone (arrow) in the right renal pelvis.

CT: computed tomography.

Courtesy of Mark D Aronson, MD.

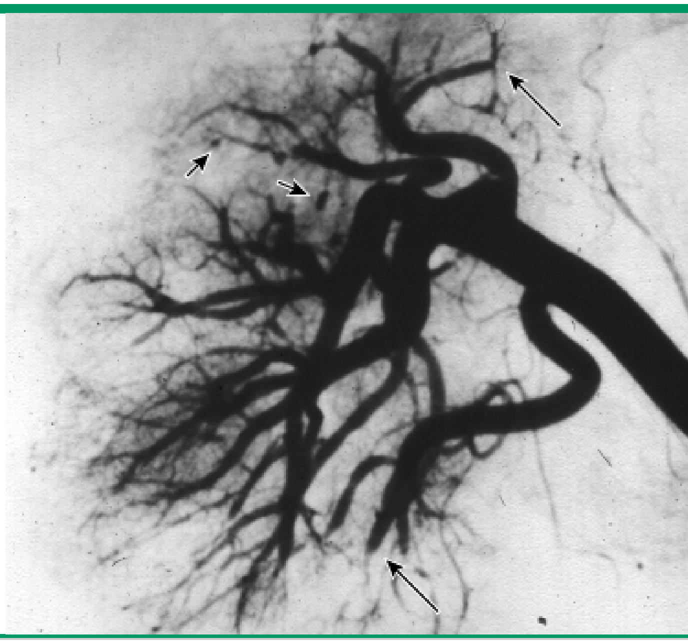
Graphic 72669 Version 9.0

Abdominal radiograph of kidney stones

Nephrolithiasis. Abdominal radiograph anteroposterior projection shows a staghorn calculus in the right renal pelvis and smaller stones (arrows) in the left kidney.

Graphic 62009 Version 6.0

Renal arteriogram in polyarteritis nodosa



Renal arteriogram in large-vessel polyarteritis nodosa showing characteristic microaneurysms (small arrows) and abrupt cutoffs of small arteries (large arrows).

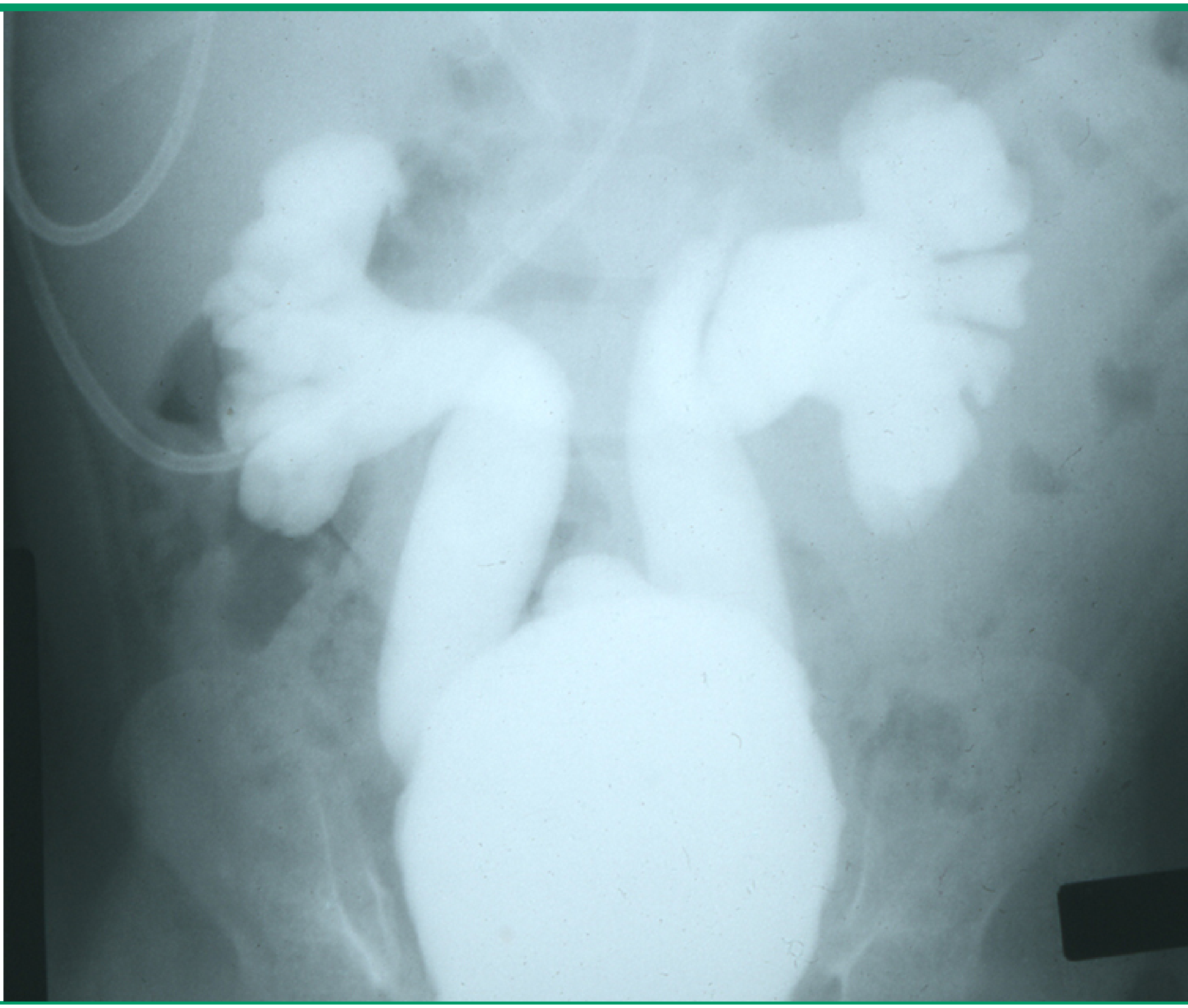
From: Rose BD. Pathophysiology of Renal Disease, 2d ed, McGraw-Hill, New York, 1987.

Graphic 65987 Version 6.0

Voiding cystourethrogram (VCUG) demonstrating unilateral Grade II vesicoureteral reflux

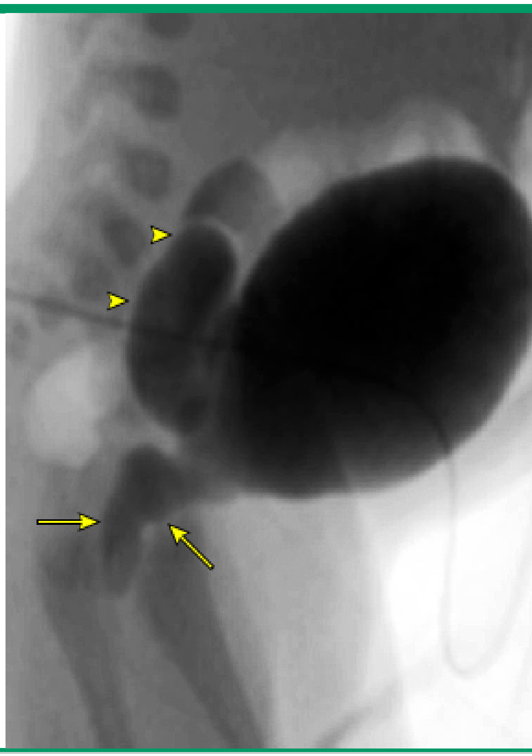
Graphic 58470 Version 4.0

Voiding cystourethrogram (VCUG) demonstrating bilateral Grade V vesicoureteral reflux



Graphic 53390 Version 3.0

Voiding cystourethrogram of patient with posterior urethral valves

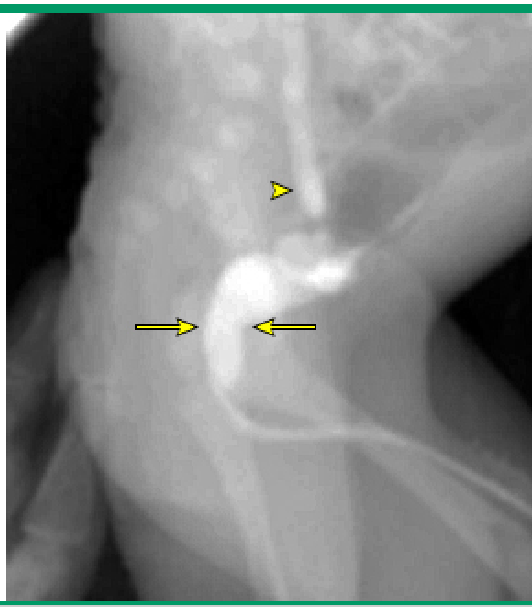


Arrows outline dilated urethra. Arrowheads outline dilated ureter with associated vesicoureteral reflux.

Courtesy of Nicholas Holmes, MD.

Graphic 62496 Version 4.0

Voiding cystourethrogram of a patient with posterior urethral valves

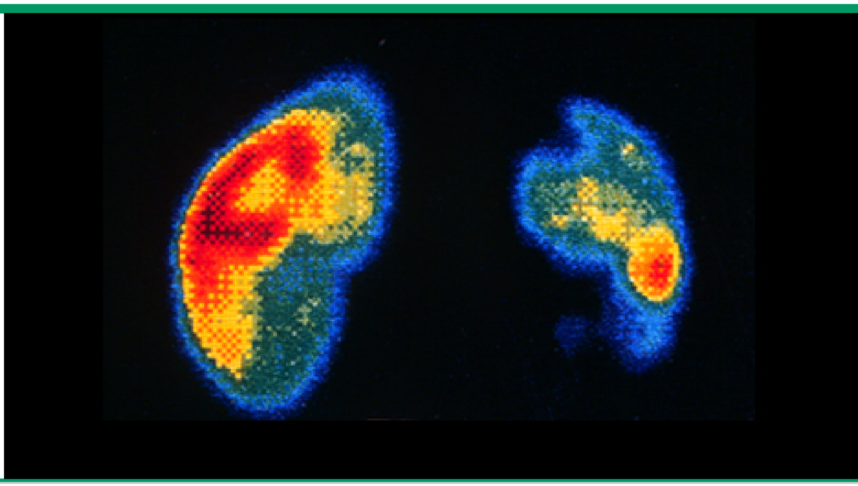


Voiding cystourethrogram of patient with posterior urethral valves noted by arrows with dilated posterior urethra. Small capacity bladder with vesicoureteral reflux (arrowhead).

Courtesy of Nicholas Holmes, MD.

Graphic 59938 Version 5.0

Acute pyelonephritis on radionuclide scan



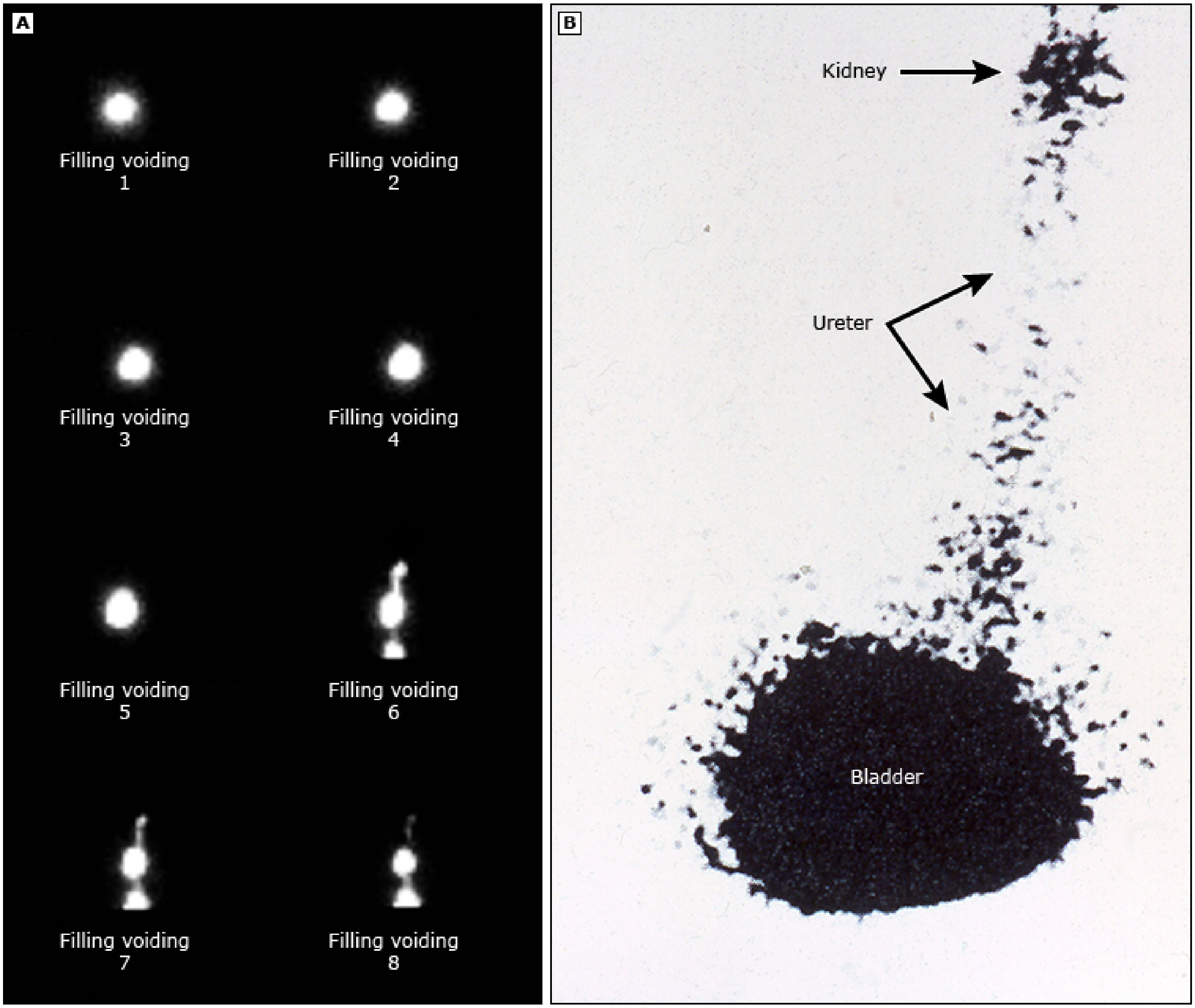
Renal scintigraphy with 99Tc-DMSA in a patient with acute pyelonephritis showing large defects in the upper and lower poles of the right kidney (which is on the right side in this view). Note smaller defects in the lower and upper pole of the left kidney, indicating that pyelonephritis, although clinically right sided, was in fact bilateral.

DMSA: dimercaptosuccinic acid.

Courtesy of Alain Meyrier, MD.

Graphic 81271 Version 4.0

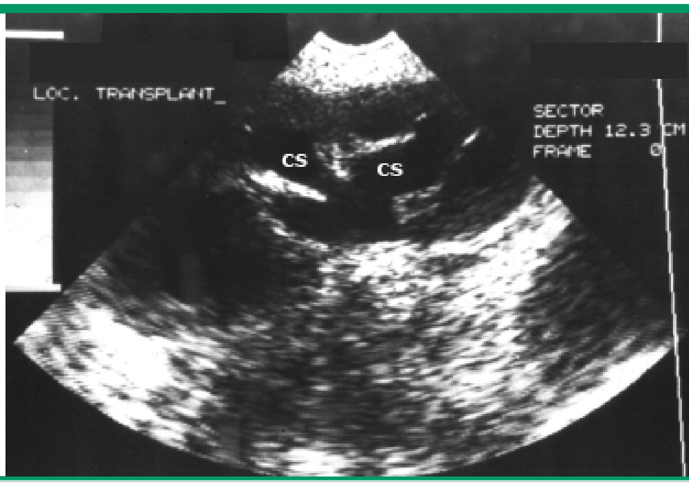
Nuclear cystogram demonstrating moderate to severe vesicoureteral reflux



(A) Series of images from a nuclear cystogram starting with filling the bladder (filling voiding 1) to demonstrating unilateral reflux to the kidney (filling voidings 6 to 8).
(B) Enlarged single nuclear cystogram demonstrating reflux from the bladder to the kidney.

Graphic 74445 Version 3.0

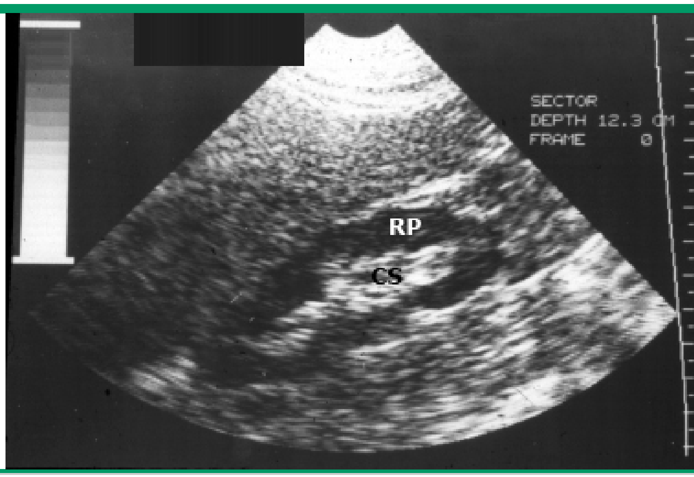
Ultrasound showing hydronephrosis



Renal ultrasonogram showing hydronephrosis due to urinary tract obstruction. The collecting structures (CS) are distended by fluid, rather than being closely bunched together as in the normal kidney. This study was performed in a renal transplant.

Graphic 77938 Version 6.0

Normal renal ultrasound



Normal renal ultrasonogram showing the renal outline and the normal width of the renal parenchyma (RP) which is represented by the black area between the renal capsule and, in white, the collecting system (CS). The collecting system structures are closely bunched together.

Graphic 63842 Version 5.0

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