abdominal radiographs

Learning a methodology for interpreting abdominal radiographs

Objective questions:

1 How can I systematically analyze an abdominal X-ray?
2 What does small bowel obstruction look like?
3 What does colon obstruction look like?
4 How can I identify free intraperitoneal air?
5 What are common causes of pneumoperitoneum?
6 What is an acute abdominal series?
7 How is CT used in abdominal imaging?
8 When is ultrasound appropriate in the abdomen?
9 Is MRI useful in abdominal imaging?

How can I systematically analyze an abdominal X-ray?

I recommend using the five basic radiographic densities as a pattern approach.

Air: Air is normally present in small amounts throughout the intestine, from the stomach to the rectum. Too much air in the intestine can be seen in obstruction and hypodynamic ileus. Sometimes air is seen outside of the bowel. This can be caused by bowel perforation, such as a gastric or duodenal ulcer or a ruptured colon diverticulum. Air can also be seen in the peritoneal cavity after abdominal surgery.

Fat: Several fat stripes are visible on an abdominal radiograph. The properitoneal fat stripe is often visible between the abdominal musculature and the colon. It is situated between the parietal peritoneum and the abdominal wall (seen laterally on AP view). Increased distance between the properitoneal fat stripe and the colon is seen in ascites. The psoas muscles also have a companion fat stripe that should be examined for symmetry. If the psoas fat stripe is absent on one side, consider an overlying inflammatory process (i.e., loss of the right psoas fat stripe in appendicitis).

Soft tissue/fluid: Soft tissue density consists of masses and the major solid organs. The liver, spleen, kidneys, and urinary bladder are the organs most likely to be seen on an abdominal film. Not only are these the largest organs, but they are also surrounded by fat and therefore can often be discerned. Other organs may become visible if they contain calcifications, such as pancreatic calcifications seen in chronic pancreatitis. Look for each solid organ on the abdominal radiograph, checking for enlargement (organomegaly) or mass. Fluid presents in the abdomen as hazy, ground-glass density. In ascites, bowel loops are pushed to the central abdomen (increased distance may be noted between the properitoneal fat stripe and the colon).

Mineral: There are many pathologic conditions in the abdomen associated with calcification:

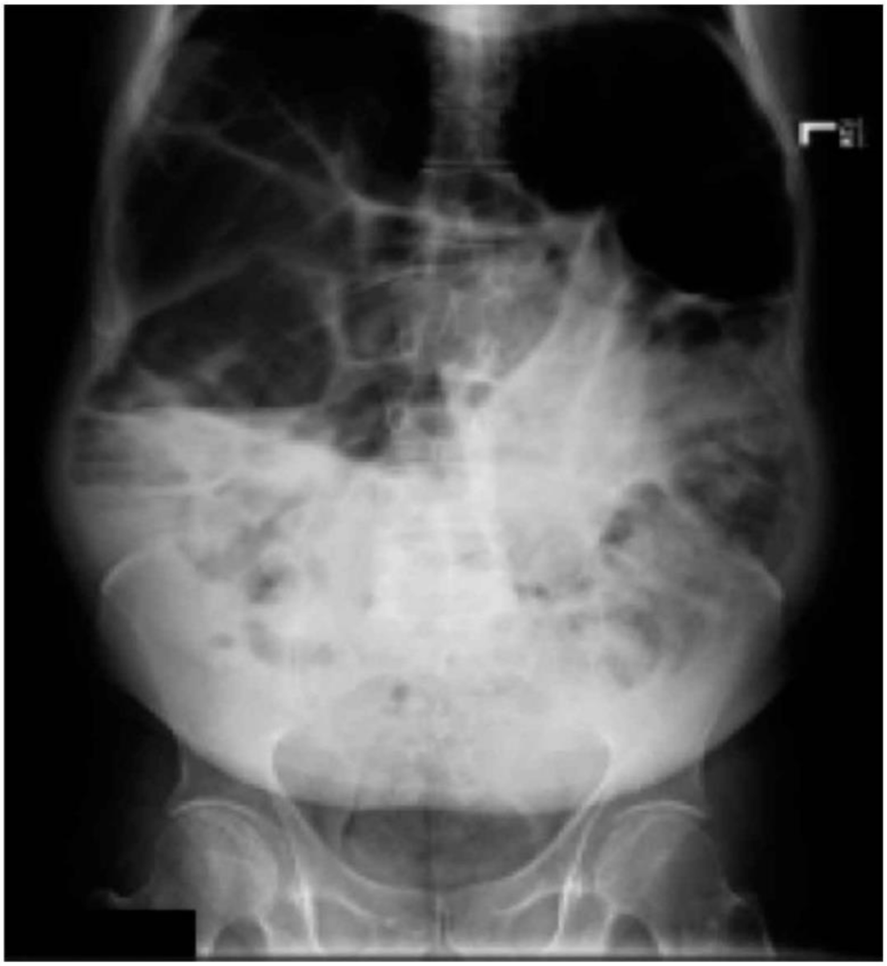
- Gallstones
- Calcified gallbladder wall (porcelain gallbladder, increased incidence of carcinoma)
- Kidney, ureteral, or bladder stones
- Pancreatic calcifications (chronic pancreatitis)
- Vascular calcification
- Splenic or hepatic calcified granulomatous disease
- Adrenal calcification (usually seen after adrenal hemorrhage)
- Appendicolith

In addition, the skeleton is mineral density that requires review. A search should be made for fractures, metastatic disease, and all other pathologic conditions affecting bone.

Metal: A search for metal density is the final step in the review of the abdomen X-ray. There are no natural metallic densities in the body. The following is a partial list of metal that may be found on an abdominal radiograph:

- Bullets, BBs, pellets
- Foreign bodies
- Surgical clips
- Recent dental work (swallowed dental amalgam)
- Swallowed objects (most often coins)
- Artifacts (snaps, lead wires, objects remaining in clothing pockets)

Hepatomegaly



Colon ileus

What does small bowel obstruction look like?

Small bowel obstruction is most often caused by postsurgical scar tissue (adhesions), but there are many other possible causes, such as tumor, foreign body, internal hernias, and external compression. Regardless of the cause, in a complete small bowel obstruction, air progressively builds up proximal to the obstruction and diminishes past the obstruction. The small bowel normally measures less than 3 cm in diameter. In obstruction, the bowel reaches and may exceed 3 cm in diameter as air builds up proximal to the obstruction. The intestine maintains a state of hypertonicity, resulting in the high-pitched active bowel sounds that are heard clinically. As fluid is propelled further in the small bowel, it too reaches the point of obstruction, creating an important radiographic sign: asynchronous air-fluid leveling (fluid leveling of unequal heights in the same bowel loop), or a “stair-step” pattern. This pattern is seen only on erect or decubitus X-rays. A fluid level is the density interface caused by fluid sinking to the gravity-dependent areas and air rising above the fluid.

Summary of findings in small bowel obstruction:

- Air-distended small bowel to 3 cm or greater
- Diminished or absent colon and rectal gas

Asynchronous air-fluid leveling (stair-step pattern)

Small bowel obstruction

CT scan: small bowel obstruction

What does colon obstruction look like?

Colon obstruction may be caused by postsurgical adhesions, tumors, inflammatory conditions such as diverticulitis, hernias, and twisting of the bowel (volvulus) among other etiologies. Because the colon is larger than the small bowel, it can distend much further, sometimes reaching 12 cm or more. Air continuously builds proximal to the obstruction and is expelled distal to the obstruction. The result is air-distended small bowel and colon to the site of the obstruction. Upright filming demonstrates air-fluid leveling, but the stair-step pattern is less pronounced or absent due to the large caliber and distensibility of the colon. In volvulus, the colon twists around an unusually long mesentery. Sigmoid volvulus presents with the shape of a coffee bean.

Summary of findings in colon obstruction:

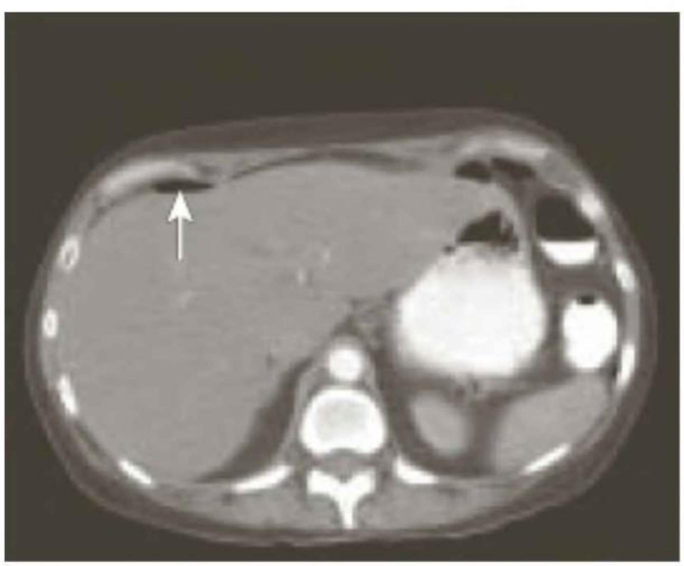
> Gas-distended colon loops that may exceed 12 cm
> Little or no air distal to the obstruction
> Air-fluid levels with little or no stair-step pattern
> Coffee-bean sign in sigmoid volvulus

How can I identify free intraperitoneal air (pneumoperitoneum)?

In radiology, we frequently use the effects of gravity to help us make a diagnosis. A great example is when we search for pneumoperitoneum. Common causes of pneumoperitoneum include recent abdominal surgery, ruptured colon diverticulum, and perforated ulcer. The best way to look for free air is with the patient sitting upright for a period of 5 to 10 minutes. Air percolates around the abdominal viscera, rising to the most gravity-independent site beneath the right diaphragm. If the patient is too unstable to sit upright, a left decubitus abdominal X-ray should be performed. In this position, the left side of the patient is down and the right side is up. Free air will collect beneath the right lateral abdominal wall. The liver serves as a good density background for recognizing the free air.

Detecting free air in the supine position is much more difficult. If there is a lot of free air, we may be able to see both sides of the bowel wall (Rigler's sign). The football sign is another possible, albeit uncommon, indicator of free air. It is caused by air collecting in the shape of a football in the right upper quadrant on both sides of the falciform ligament.

Pneumoperitoneum



Free air anterior to liver

What are common causes of pneumoperitoneum?

Recent abdominal surgery, open or laproscopic, always results in at least a small amount of free air. This air is slowly absorbed into the bloodstream. Delayed pneumoperitoneum can last several weeks (there has been a report of residual air eight weeks after surgery). With no history of surgery, a ruptured colon diverticulum and a perforated gastric or duodenal ulcer are the most common causes of pneumoperitoneum. Air can be introduced into the peritoneal cavity through trauma or iatrogenic means, such as viscus perforation during endoscopy.

What is an acute abdominal series?

An acute abdominal series is one of the most common X-ray requests made in the emergency department. Three views are obtained: a supine abdominal film, an erect or left lateral decubitus abdominal film, and a PA chest X-ray. The supine abdomen is used to assess the intestinal gas pattern, look for organ enlargement or mass, search for pathologic calcifications such as kidney stones, and rule out opaque foreign bodies. The erect abdominal film must include both diaphragms. Free intraperitoneal air will rise to the area beneath the diaphragms. The erect film also allows for the assessment of air-fluid levels in the bowel. Synchronous air-fluid levels are seen in hypodynamic ileus, while asynchronous air-fluid levels are seen in dynamic ileus (obstruction). The PA chest X-ray gives you one more chance to evaluate for air under the diaphragms, but it is primarily used to look for chest causes of abdominal pain, such as lower lobe pneumonia. Some abdominal conditions, such as pancreatitis, will present with pleural effusion, which is best seen on the chest X-ray.

Films obtained in an acute abdominal series:

> Supine abdominal X-ray
> Erect or left lateral decubitus abdominal X-ray
> PA chest

How is CT used in abdominal imaging?

CT is the procedure of choice for nearly any abdominal condition, with the exception of gallbladder pathology, for which ultrasound is superior. Common reasons to request an abdominal CT are pain, suspected mass pathology, and metastasis. Reasons to order an abdominal CT include the following:

> Abdominal aortic aneurysm
> Abdominal metastatic disease
> Abdominal trauma (lacerated spleen, liver, or kidney)
> Adrenal masses
> Appendicitis
> Cirrhosis
> Diverticulitis
> Gallbladder abscess (phlegmon)
> Hepatic metastatic disease
> Inflammatory bowel disease
> Pancreatic cancer

Pancreatitis (acute, subacute, or chronic)
Renal calculus disease
Renal mass (benign or malignant)

Acute pancreatitis

Inflammatory changes; mesenteric fat

When is ultrasound appropriate in the abdomen?

Ultrasound is best for vascular structures, fluid-filled structures, the female pelvis, and the scrotum. It is generally best for fluid imaging. Ultrasound uses no radiation, can be performed regardless of organ failure, and is readily available. Large patients and patients with gaseous distention of bowel are poor candidates for ultrasound because air tends to scatter the sound rather than conducting it or reflecting it back to the transducer. Reasons to order an abdominal ultrasound include the following:

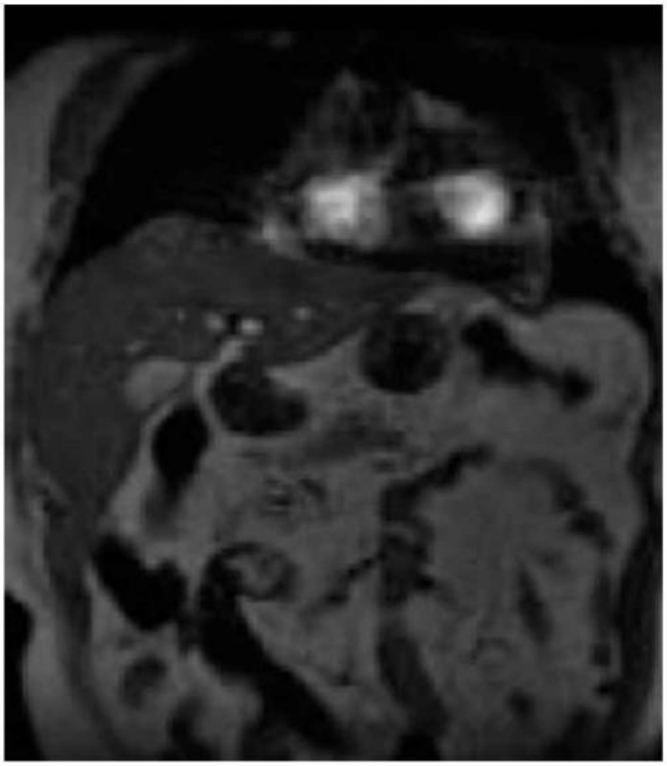
- Gallstones and other gallbladder disease
- Abdominal aortic aneurysm
- Appendicitis (especially in children)
- Pyloric stenosis
- Renal cyst
- Renal obstruction

Is MRI useful in abdominal imaging?

MRI adds an additional set of imaging characteristics to the evaluation of any type of pathology. For example, MRI can help differentiate hepatic hemangioma from hepatic adenoma or other tumor. Because MRI can reveal information about the water content, lipid content, and tissue vascularity of a structure, we can use this information to refine the differential diagnosis or make a specific diagnosis. Usually, when multiple imaging modalities are combined, the information obtained leads to a more specific diagnosis. A great example is an adrenal mass. Because 70% of benign adrenal adenomas contain lipid, and because MRI can demonstrate lipid signal characteristics, a specific diagnosis is made possible. Abdominal MRI is generally used to clarify an existing imaging finding from another modality by adding information about tissue characteristics. Reasons to order an abdominal MRI include the following:

- Hepatic hemangioma
- Other hepatic tumors that continue to have an unclear diagnosis on CT or ultrasound
- Bile duct dilatation (magnetic resonance cholangiopancreatography [MRCP])
- Arterial pathology (magnetic resonance angiography [MRA])
- Staging endometrial cancer
- Staging prostate cancer

Ultrasound of cholelithiasis



MRI: gallbladder

URINARY

Selecting the best studies to image the GU system

Objective questions:

1 When should I request a GU study?
2 What is an IVP and how is it performed?
3 How do I evaluate an IVP?
4 What are the IVP, CT, and ultrasound findings in obstructive uropathy?
5 What are the imaging findings in kidney cancer?
6 How can I be sure that a renal mass is truly cystic?
7 How can I locate the adrenal glands on CT and what are the common pathologies?
8 How is the prostate gland imaged?
9 How are the testicles imaged? What are the common pathologies?

When should I request a GU study?

Stone disease, infection, trauma, neoplasia, and vascular diseases are the most common maladies affecting the genitourinary system. Hematuria is a symptom that must be considered a sign of possible cancer anywhere from the kidney to the bladder. For this reason, cross-sectional imaging with CT, MRI, and/or ultrasound is important when screening for cancer.

Common reasons to request a genitourinary imaging study:

> Kidney, ureter, or bladder calculus
> Hematuria of unknown origin
> Flank pain
> Recurrent urinary tract infection
> Suspected renal, ureteral, or bladder cancer
> Scrotal mass
> Suspected testicular torsion

What is an IVP and how is it performed?

An intravenous pyelogram (IVP), also known as an intravenous urogram, is an examination performed by the intravenous administration of iodinated contrast. Contrast is filtered by the kidneys, allowing for assessment of renal cortical function, filling of the renal collecting systems, the ureters, and the urinary bladder.

Multiple films are obtained to demonstrate the sequential functioning of these structures. Recently, CT has supplanted IVP in many imaging centers because it is quick, accurate, and allows for more detailed assessment of renal anatomy. Cysts and tumors are more accurately evaluated with CT. Ultrasound is helpful for confirming a renal mass as a cyst and for detecting a dilated intrarenal collecting system (hydronephrosis).

TEACHING POINT

In many centers, CT has supplanted IVP for the assessment of stone disease and obstructive uropathy.

Normal IVP

Coronal CT: kidneys

How do I evaluate an IVP?

The following steps can be used as a general guide for evaluating an IVP. An IVP is one of the few X-ray tests that allow us to determine the function of an organ. Most other imaging studies are simply static images that provide anatomic detail.

1. The scout films should be reviewed looking specifically for mineral (calcium) density overlying the kidneys or along the expected course of the ureters.
2. After contrast is given, radiographs are obtained at 1, 3, 5, and 10 minutes.
3. By 1 minute, the glomeruli and tubules begin to opacify (nephrographic phase).
4. By 5 minutes, the calyces and renal pelvis should be seen bilaterally (pyelographic phase). If there is an obstruction, a delay in the pyelographic phase on the affected side will be noted.
5. By 10 minutes, the ureters and bladder are visible. If there is obstruction, the ureter on the affected side may not yet be opacified or it may be seen to be dilated (ureterectasis).
6. If there is an obstruction, it may be necessary to obtain delayed radiographs up to several hours in an attempt to visualize the ureter and the site of obstruction.
7. The bladder should be distended by 10 minutes. Assess the bladder for filling defects that may reflect a stone or tumor.
8. Finally, the postvoid film is obtained to determine the ability of the patient to empty the bladder.

What are the IVP, CT, and ultrasound signs of obstructive uropathy?

Any of these three imaging modalities may be used to detect obstruction of the urinary tract. Choose an IVP if you are interested in evaluation of renal function, CT if you suspect a kidney/ureteral calculus or renal tumor, and ultrasound if you wish to avoid radiation.

Summary of imaging findings in obstructive uropathy:

IVP:

1. Delay in the nephrographic and/or pyelographic phase.
2. Distention of the calyces, renal pelvis, and ureter to the level of the obstruction.

CT:

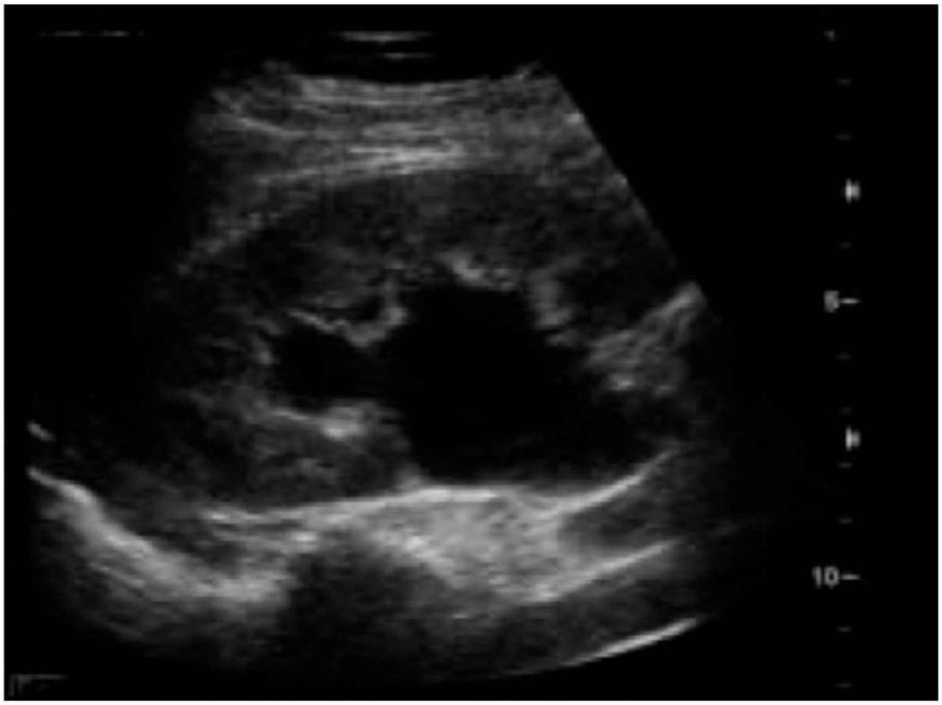
1. Contrast distention of the calyces and pelvis on the obstructed side.
2. Distention of the ureter to the site of obstruction.

Ultrasound:

1. Distention of the renal pelvis and calyces. The urine is anechoic (free of echoes) within the dilated collecting system.
2. The appearance of the pelvis and calyceal distention is likened to a bear paw.


POST VOID

Left ureteral obstruction



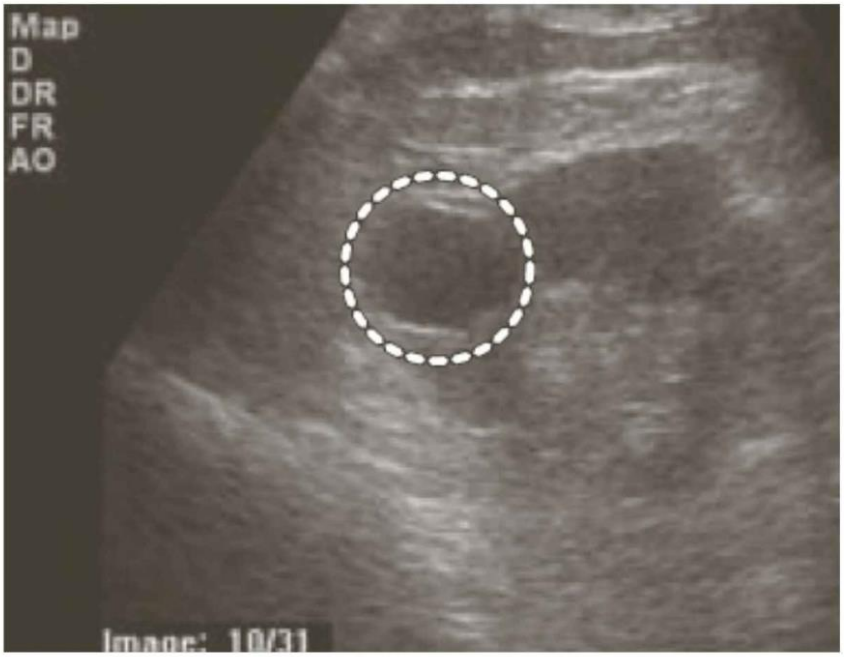
Ultrasound: renal obstruction

What are the imaging findings in kidney cancer?

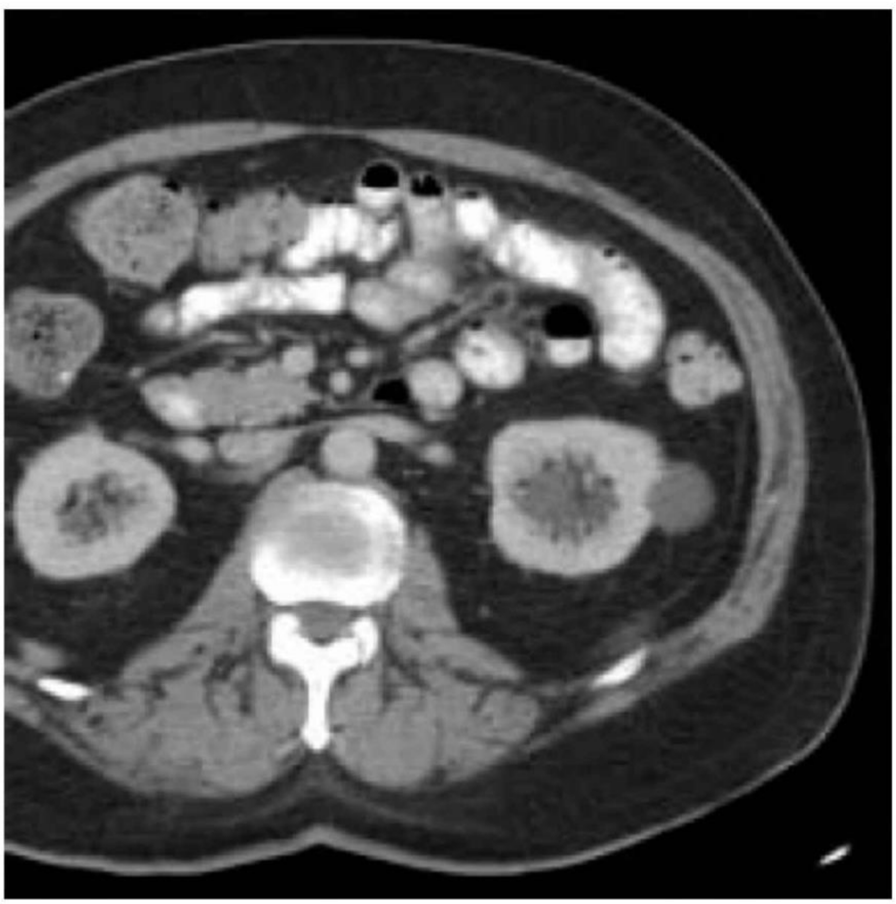
A renal mass will occasionally be visible on the abdominal plain film. When the plain film or the IVP is evaluated, the renal margins should be closely scrutinized. Kidney cancer most often presents with an abnormal contour bulge.

With CT, renal malignancy presents as a soft tissue mass that is solid and often lobulated. The lesion may be identical in density to the normal renal parenchyma on the noncontrasted images. With contrast, the kidney tumor becomes visible, often displaying areas of nonuniform enhancement. Renal neoplasms are extremely vascular. Rapid growth may outstrip the blood supply, resulting in central areas of low density, indicating tumor necrosis within the mass. The contour of the kidney is usually distorted and the collecting system is compressed and/or displaced. MRI will also demonstrate variations in signal intensity within a renal malignancy. CTA or MRA can be helpful to depict the relationship of the tumor to the renal artery or arteries (there is frequently more than one artery supplying the kidney). Imaging must also address the possibility of tumor invasion into the renal vein or inferior vena cava. Both contrast CT and MRI can detect this invasion, demonstrating a filling defect occupying the vessel lumen.

Ultrasound is excellent for distinguishing cyst from solid. All solid lesions are suspect for malignancy. Any complex cyst—that is, a cyst that has septa, wall thickening, or internal debris or contains a soft tissue mass—must be regarded as potentially malignant. If an ultrasound uncovers a solid renal mass or complex cyst, CT or MRI will then be indicated for further evaluation.



Ultrasound: renal cyst



Simple renal cyst: left kidney

How can I be sure that a renal mass is truly cystic?

It is important to confirm that a renal cystic lesion is simple. A simple cyst is always benign, but some cystic lesions are malignant. CT, ultrasound, or MRI can be used to confirm simple renal cyst.

A simple cyst on CT

1. Has no perceptible wall.
2. Has CT density measurements of 0.
3. Has no septa, mural nodules, or internal debris.
4. Is sharply circumscribed and round or oval in shape.

A simple cyst on MRI

1. Has no perceptible wall.
2. Is composed of water signal on all sequences (bright on T2, black on T1).
3. Has no septa, mural nodules, or internal debris.
4. Is sharply circumscribed and round or oval in shape.

A simple cyst on ultrasound

1. Is completely void of internal echoes.
2. Is round or oval in shape.
3. Displays increased through-transmission of sound.

How can I locate the adrenal glands on CT and what are the common pathologies?

The adrenal glands are located just superior and medial to the kidneys, usually on the 2–3 slices above the tops of the kidneys. These small structures can be hard to find in thin patients who do not have much intrabdominal fat. The adrenal glands are composed of two or three thin limbs that intersect at a small circular hilum. They most often have the shape of the letter Y or V. Adrenal adenomas are the most common adrenal pathology seen on CT. Adenomas are round or oval masses that are of slightly lower attenuation than the normal adrenal tissue because approximately 70% of them are composed of a partial lipoid matrix. Adrenal hyperplasia is also fairly common, presenting with diffuse thickening of the adrenal limbs. Primary adrenal carcinoma is relatively rare. These masses are usually larger than 2 cm and may have a necrotic center. More common is adrenal metastasis. In fact, adrenal metastasis in lung cancer is common enough that we always include the adrenal glands on all chest CT scans.

CT: normal adrenal gland

Left adrenal nodule

How is the prostate gland imaged?

The prostate gland is well studied with ultrasound using a rectal probe. Well-defined zones of anatomy are easily demonstrated by ultrasound. Biopsy can be performed using this same specialized ultrasound probe.

MRI is also an excellent modality for the prostate gland. A specialized rectal coil is employed to provide excellent MR signal detail. MRI is especially useful for staging known prostate cancer.

Ultrasound is most often employed

> As a screening test
> To follow up an elevation of the prostate-specific antigen (PSA)
> To study a palpable prostate nodule
> To guide biopsy

How are the testicles imaged? What are the common pathologies?

Scrotal ultrasound is a quick and painless way to image the scrotal contents. Fluid accumulation (hydrocele) is easily identified. Doppler ultrasound is used to confirm arterial flow to the testes. Common pathologies that can be detected with scrotal ultrasound include hydrocele, vericocele, spermatocele, testicle torsion, epididymitis, and testicle tumors. Torsion of the testicle is an emergency that requires early detection to prevent infarction and irreversible testis damage.