Emergent Right Upper Quadrant Sonography

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Objective. The purpose of this presentation is to review the sonographic spectrum of disease entities evaluated by right upper quadrant (RUQ) sonography on an emergent basis. ***Methods.*** Right upper quadrant sonography was performed on an emergent basis in patients who came to the emergency department with signs and symptoms suspicious for or simulating acute cholecystitis or diseases of the liver and biliary tree. ***Results.*** A wide gamut of acute and chronic cholecystitis and diseases of the liver and biliary tree were visualized on RUQ sonography. Several other entities in addition to hepatic and biliary disease were also suspected on sonography and further evaluated by computed tomography. ***Conclusions.*** Right upper quadrant sonography is the first line of imaging in patients with signs and symptoms of hepatic, gallbladder, or biliary disease as well as RUQ pain. Patient triage or additional imaging may be obtained on the basis of emergent RUQ sonographic findings. ***Key words:*** biliary dilatation; cholecystitis; gallbladder; liver; pancreatitis.

Abbreviations
CT, computed tomography; HIV, human immunodeficiency virus; IVC, inferior vena cava; RUQ, right upper quadrant

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Right upper quadrant (RUQ) sonography is one of the most common emergent ultrasound examinations performed. It is relatively inexpensive and noninvasive and is the initial diagnostic imaging modality in the emergency setting for evaluating acute RUQ pain.[1,2] It is also an appropriate initial diagnostic modality when clinical concerns include biliary disease, elevated liver function test values, and routine evaluation of the liver in the setting of hepatitis C and elevated α-fetoprotein levels.

At our institution, RUQ sonography includes evaluation of the liver, gallbladder, central biliary tree, pancreas, inferior vena cava (IVC), and right kidney. Color Doppler evaluation of portal vein patency and the direction of flow is also included. Table 1 lists some basic normal values to allow a framework for evaluating pathologic conditions.

Table 1. Normal Values

Echogenicity: pancreas > liver ≥ kidney
Liver span: 13–17 cm at the midclavicular line
Intrahepatic ducts: <40% of the diameter of the adjacent portal vein, peripheral ducts <2 mm in diameter
Common bile duct: 7 mm at mid duct (noncholecystectomy, age <60 y)
Gallbladder: <4 cm transverse, 10 cm longitudinal
Gallbladder wall: <3 mm
Pancreas: head <3 cm, body <2.5 cm, tail <2cm
Pancreatic duct: <3 mm
Portal vein: <13 mm where the portal vein crosses the IVC in a supine patient
Splenic vein: <6 mm

Normal values are from Middleton et al[3] and are for general reference. Not all normal values given here are universally agreed on.

Figure 1. Single large gallstone (arrow) with a clean acoustic shadow.

Gallbladder

Cholelithiasis and Its Mimickers

Right upper quadrant sonography is the study of choice for evaluating the gallbladder, offering improved resolution of gallbladder disease over computed tomography (CT). It is useful for subdividing the pathologic conditions commonly encountered into acute, chronic, and incidental.

In the acute setting, conditions that are often encountered range from uncomplicated cholelithiasis to acute cholecystitis. The typical appearance of gallstones on sonography varies according to the size and number of the stones and their calcium content. Patients may have a single large gallstone (Figure 1) or many small ones. Simple small gallstones can be seen as multiple echogenic foci layering within the gallbladder lumen, with posterior acoustic shadowing (Figure 2). In the event that a large number of gallstones are present within the gallbladder, the gallbladder may contract around them, and the contracted gallbladder may be difficult to visualize separately from the stones. This creates what is known as the "wall-echo-shadow" sign (Table 2), in which the wall of the gallbladder is seen immediately anterior to bright echoes from multiple stones, and posterior acoustic shadowing then dominates the picture (Figure 3). This may be difficult to differentiate from a porcelain gallbladder or an emphysematous gallbladder wall, at which point CT may provide additional information.[4]

Gallstone Mimics

A rounded, isoechoic to slightly hyperechoic structure is identified within the gallbladder, with no posterior acoustic shadowing, representing a "sludge ball" (Figure 4). Its mobility distinguishes it from a tumor or polyp, however non shadowing gallstones, aggregate pus or clot can also have a similar appearance.

Acute Cholecystitis

In the emergency setting, evaluation for acute cholecystitis is the most common indication for ordering RUQ sonography because clinical or laboratory parameters are unable to confirm or exclude this diagnosis without further imaging.[5] Acute cholecystitis may have a wide range of

Figure 2. Multiple gallstones: sagittal view of the gallbladder showing multiple echogenic foci (arrow) layering in the dependent portion of the gallbladder with faint acoustic shadowing.

Table 2. Right Upper Quadrant Sonographic and CT Signs

Murphy sign: Acute focal pain over the gallbladder when pressure is applied with the transducer; while this is often a very sensitive sign for acute cholecystitis, this may be negative with heavy medication or gangrenous cholecystitis.
Wall-echo-shadow sign: Produced by a gallbladder full of stones; this can be mimicked in a porcelain gallbladder or emphysematous changes.
Mercedes-Benz sign: Air in degenerating gallstones seen on CT.
Comet tail artifact: Seen in adenomyomatosis, cholesterol crystals deposited in Rokitansky-Aschoff sinuses result in bright reflections and short comet tail artifacts arising in the gallbladder wall.
Strawberry gallbladder: The gross description of cholesterolosis in the gallbladder; lipid deposits within the lamina propria of the gallbladder wall will give it a strawberrylike appearance.
Ball on the wall sign: Seen with small cholesterol polyps; small polyps are enlarged papillary fronds filled with lipid-laden macrophages attached to the gallbladder wall with a stalk; the stalk is rarely visible, so they typically appear as masses attached to the wall.
Porcelain gallbladder: Calcifications in the wall of the gallbladder indicative of chronic inflammation.
Target/rim sign: On CT, a common duct stone may appear as a central density surrounded by a rim of lower-density bile; low-attenuation stones may be defined by a higher-attenuation outer rim (rim sign).
Starry sky sign: Often seen in acute hepatitis, the relative increased echogenicity of the portal triads in relation to the liver often appears as small bright areas in the periphery of the liver.
Cavernization of the portal vein: In the setting of portal vein thrombosis, collaterals form through the vasa vasorum of the portal vein.
Beaded pancreatic duct: In the setting of chronic pancreatitis, focal areas of narrowing and dilatation of the pancreatic duct cause a beaded appearance.

appearances and severity, from gallbladder wall edema and pericholecystic fluid to emphysematous, hemorrhagic, or gangrenous cholecystitis. It is crucial to be aware of the range of presentations of this extremely common entity.

Most cases of acute cholecystitis are acute calculous cholecystitis, most often related to obstruction of the cystic duct by a gallstone.[2] The finding of gallstones in combination with maximal tenderness localized over the gallbladder (sonographic Murphy sign) has a 92.2% positive predictive value for acute cholecystitis (Figure 5).[6]

Although gallbladder wall edema is one of the first signs of acute calculous cholecystitis, gallbladder wall thickening and pericholecystic fluid may be nonspecific and are often seen in other conditions such as hepatic congestion, liver disease, right heart failure, renal disease, inflammation in the adjacent organs, and fluid (ascites or localized inflammation). In these cases, secondary findings, the clinical history, and laboratory values are essential to make a correct diagnosis.

Figure 3. Wall echo shadow sign. In a gallbladder full of stones, a reflection with a prominent acoustic shadow emanates from the gallbladder fossa. The first line is the echogenic interface of the liver and gallbladder with the hypoechoic wall of the gallbladder (curved arrow); the second is the bright echoes of the gallstones (arrow) followed by dense acoustic shadowing behind the stones.

Figure 4. Sludge ball: longitudinal view of the gallbladder shows a rounded hyperechoic, mobile, nonshadowing mass (arrow) in the dependent portion of the gallbladder lumen.

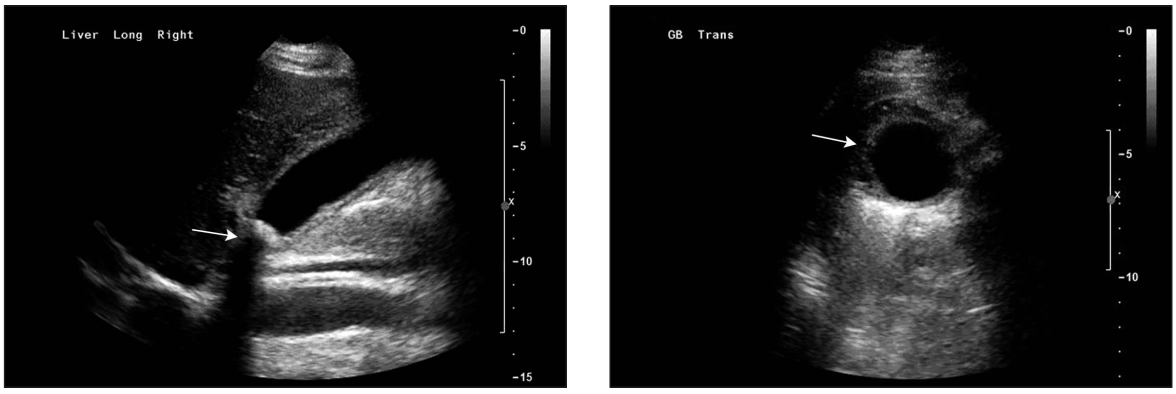

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Figure 5. Acute cholecystitis and gallbladder wall edema. **A**, Sagittal view showing a gallstone (arrow) impacted at the gallbladder neck with posterior shadowing and wall edema. **B**, Transverse view from the same patient. The wall is thickened according to the size criterion of greater than 3 mm (arrow) with a small amount of pericholecystic fluid.

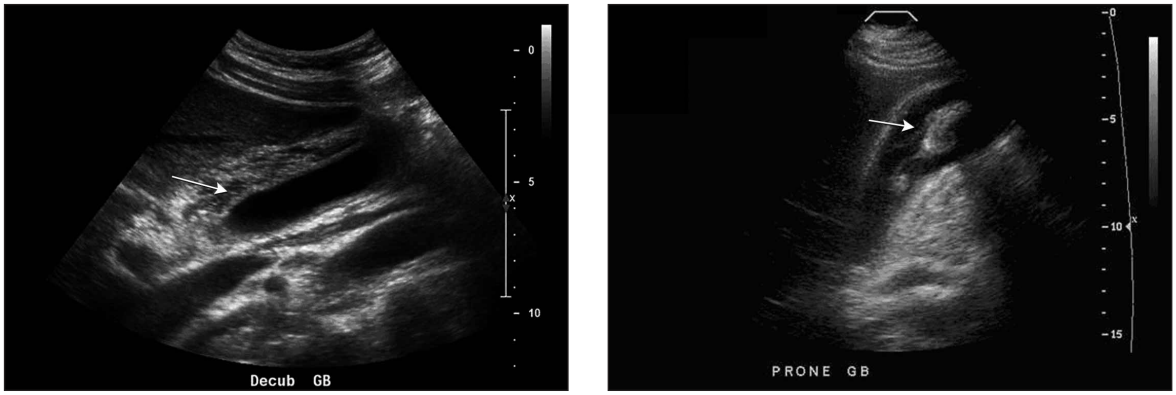
Complicated Acute Cholecystitis:

Acute cholecystitis may progress with presentation in an advanced stage and development of concomitant complications. Alternating hyperechoic and hypoechoic bands in an irregularly thickened gallbladder wall suggest advanced cholecystitis and wall necrosis (Figure 6). Irregular linear echoes in the gallbladder lumen are intraluminal membranes caused by fibrous exudates or necrosis and sloughing of the gallbladder mucosa. This is a relatively specific finding seen in rare cases of gangrenous cholecystitis (Figure 7). It should be noted that, unlike most cases of acute cholecystitis, the sonographic Murphy sign is present in only approximately 33% of patients with gangrenous cholecystitis, and a negative Murphy sign should not sway the radiologist from the diagnosis of this severe form of acute cholecystitis.[7]

Echogenic foci from the nondependent portion of the gallbladder wall may show dirty shadowing suggestive of gas in the gallbladder wall and may change in position on moving the patient (Figure 8).[8] This gas may mimic a gallbladder full of stones or porcelain gallbladder. Perforation of the gallbladder is 5 times more likely with emphysematous cholecystitis than with simple gallstone-induced cholecystitis. Although sonography remains a valuable first-line imaging tool if perforation is suspected,[9] if the etiology of the shadowing remains in doubt after sonography, CT may be helpful to further elucidate the cause.[10]

Figure 6. Complicated acute cholecystitis with alternating hyperechoic and hypoechoic bands (arrow) in an irregularly thickened gallbladder wall.

Figure 7. Linear irregular echoes (arrow) intraluminally within the gallbladder with sloughing of the mucosa.



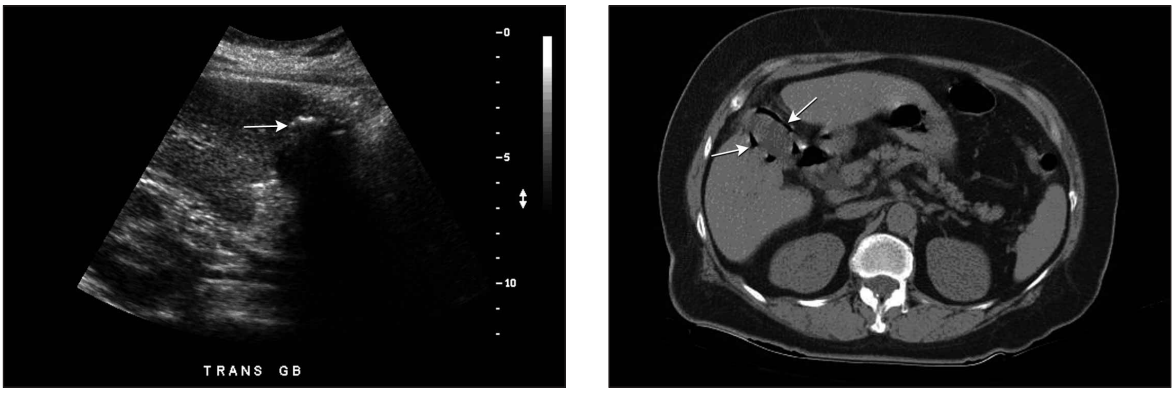


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Figure 8. Emphysematous cholecystitis. **A**, Sonogram showing echogenic foci in the nondependent portion of the gallbladder wall with dirty shadowing suggestive of gas in the gallbladder wall (arrow). **B**, Computed tomogram showing multiple foci of air within the gallbladder wall (arrows).

Acute Acalculous Cholecystitis:

Acalculous cholecystitis, as the name suggests, represents inflammatory changes of the gallbladder in the absence of an obstructing gallstone. This entity is more commonly seen in the intensive care unit setting. Trauma, mechanical ventilation, and hyperalimentation are predisposing factors that contribute to bile stasis, functional cystic duct obstruction, and ischemia in cases of acalculous cholecystitis.[11] A sonographic diagnosis of acalculous cholecystitis is made by showing gallbladder wall edema and possibly sludge in the gallbladder lumen. A positive sonographic Murphy sign is extremely helpful, although a negative Murphy sign does not exclude the disease. It should be noted, however, that if gallbladder wall edema is identified in isolation, other conditions that can result in wall edema must be excluded in these patients, who are generally critically ill, such as congestive heart failure, hypoalbuminemia, ascites, and a fluid overload (Figure 9).

Incidental and Chronic Gallbladder Conditions

While imaging the gallbladder in the acute setting, it is important to recognize the common chronic and incidental conditions that may be encountered so that they may be appropriately discounted or followed. Gallbladder polyps are small, nondependent, nonmobile foci that adhere to the gallbladder wall, with cholesterol polyps being the most common type (Figure 10). Cholesterol polyps are not true neoplasms but rather papillary fronds filled with lipid-laden

Figure 9. Acute acalculous cholecystitis: sagittal view showing a distended gallbladder with an edematous wall and pericholecystic fluid (arrow). No gallstones are present.

Figure 10. Sagittal view showing echogenic nonmobile, nonshadowing foci (arrows) adherent to the gallbladder wall.

macrophages that are attached to the wall via a slender stalk. The stalk may be too small to be seen, leaving a small rounded focus adherent to the gallbladder wall, also known as the "ball on the wall" sign. Cholesterol polyps are usually smaller than 5 mm; larger polyps (>5 mm) are generally followed for 6 to 12 months for stability,[3] although their likelihood of malignant transformation is generally low.[12]

Adenomyomatosis is a frequently encountered condition that is generally associated with chronic low-grade inflammatory changes within the gallbladder. It is characterized by mucosal hyperplasia and focal (Figure 11) or diffuse (Figure 12) thickening of the gallbladder wall. It is pathologically associated with mucosal herniation into Rokitansky-Aschoff sinuses, which subsequently results in bright refractions on sonography, known as the "comet tail" sign (Figure 13).

"Porcelain gallbladder" is the term commonly used when the gallbladder wall is diffusely calcified, although calcification is not necessarily circumferential. It occurs in the setting of chronic inflammation and is considered a risk factor for gallbladder carcinoma, with most patients receiving this diagnosis subsequently undergoing cholecystectomy. On sonography, depending on the extent of calcification, the gallbladder will appear as an echogenic arc with posterior shadowing (Figure 14). This appearance may be confusing because it is similar to the wall-echo-shadow sign in a gallbladder filled with stones or air in the gallbladder wall. In an acute setting, if the diagnosis remains in doubt after sonographic evaluation, cross-sectional imaging should be considered.

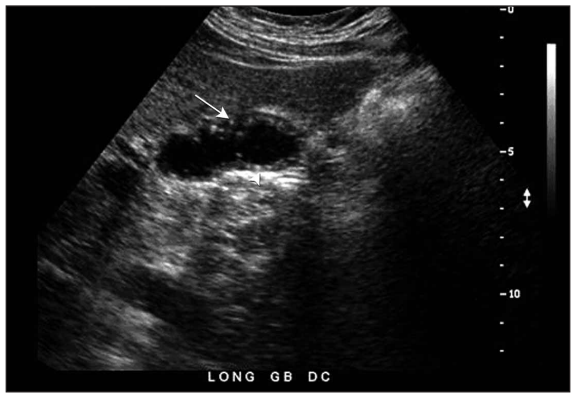


Figure 12. Diffusely nodular appearance on the nondependent (arrow) and dependent (arrowhead) walls, consistent with adenomyomatosis.

Xanthogranulomatous cholecystitis is an uncommon form of chronic cholecystitis thought to be due to extravasations of bile into the gallbladder wall, through either mucosal ulceration from chronic cholecystitis or rupture of Rokitansky-Aschoff sinuses from increased intraluminal pressure in the setting of cystic duct obstruction. The most common sonographic features of cholelithiasis and focal or diffuse gallbladder wall thickening are usually nonspecific (Figure 15).[13] The most specific sonographic findings include the presence of hypoechoic nodules or bands in the gallbladder wall, which are seen in 35% of the patients.[14]

Human immunodeficiency virus (HIV) cholangiopathy involves primary HIV infection of the gallbladder and biliary tree. In the acute setting, abdominal pain in an HIV-positive patient with a

Figure 11. Focal changes of adenomyomatosis at the gallbladder fundus (arrow).

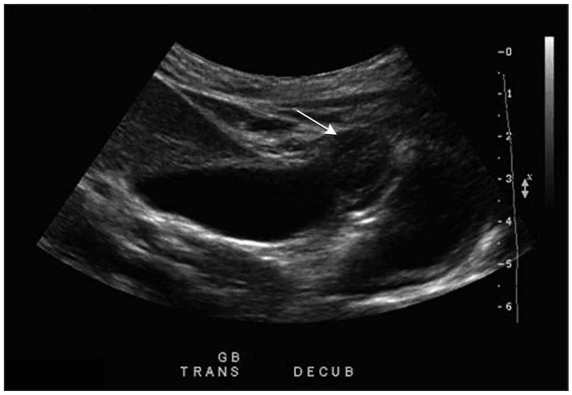
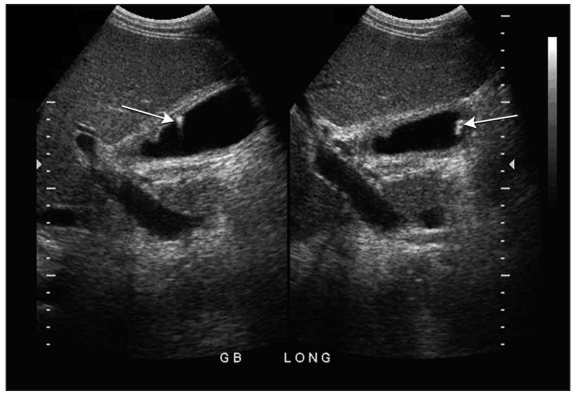


Figure 13. Longitudinal views of the gallbladder showing mucosal herniation into Rokitansky-Aschoff sinuses, resulting in bright refractions and the comet tail sign (arrows).



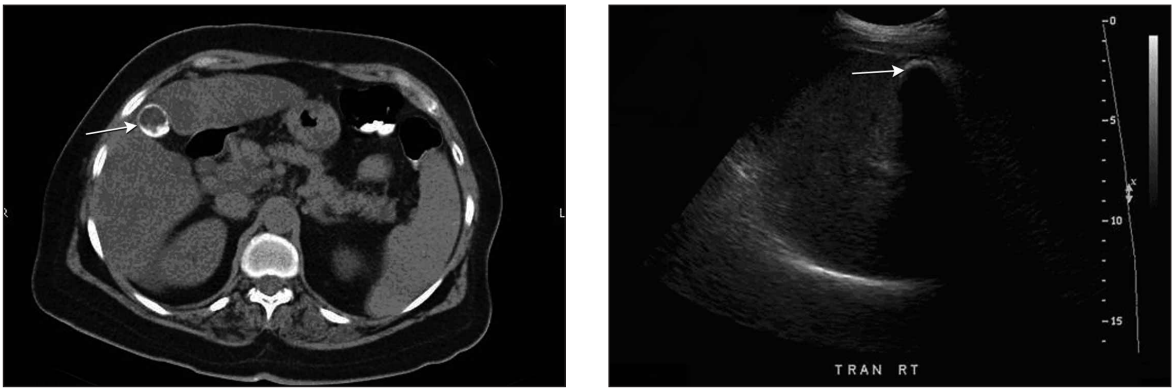


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Figure 14. Porcelain gallbladder. **A**, Computed tomogram showing a densely calcified gallbladder wall (arrow). **B**, Sonogram from the same patient showing a calcified gallbladder wall (arrow) with dense posterior acoustic shadowing. Air within the gallbladder wall or large gallstones may also create this appearance.

sonographic finding of gallbladder wall thickening without gallstones or pericholecystic fluid should suggest HIV cholangiopathy. However, opportunistic infections must always be kept in the differential diagnosis, with the most common opportunistic infections of the biliary tree being *Cryptosporidium*, *Cytomegalovirus*, and *Microsporidium* (Figure 16).

Gallstone Ileus

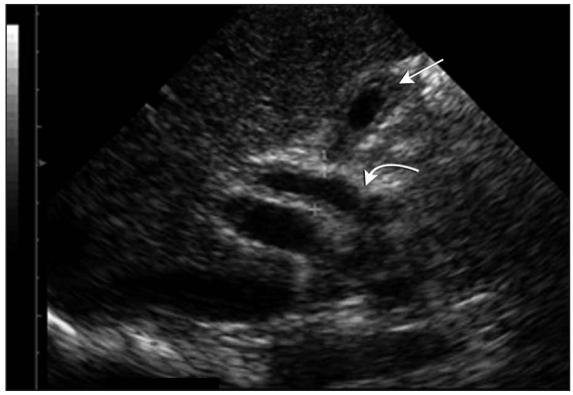
Gallstone ileus is a somewhat rare condition in which a gallstone erodes through the gallbladder wall and via a fistulous enteric connection enters adjacent loops of small bowel. The gallstone then becomes impacted at the level of the ileocolic valve, causing proximal small-bowel obstruction. The term "ileus" is a misnomer in this mechanical obstruction. In the case of gallstone ileus shown here (Figure 17), sonography shows a reverberation artifact in the gallbladder fossa and intrahepatic ducts. Computed tomography shows pneumobilia and dilated loops of bowel. An impacted gallstone was identified at the terminal ileum.

Biliary Tree

Elevated liver function test values and elevated bilirubin levels are common indications for emergent RUQ sonography. Obstructive lesions can cause biliary dilatation at multiple levels, and the pattern of biliary dilatation, whether it is intrahepatic, extrahepatic, or combined, allows for an appropriately tailored differential diagnosis.

Figure 15. Xanthogranulomatous cholecystitis: sagittal view of the gallbladder showing a hypoechoic nodule (arrow) in the gallbladder wall.

Figure 16. Human immunodeficiency virus cholangiopathy with diffuse mural thickening of the gallbladder (arrow) and common bile duct (curved arrow).



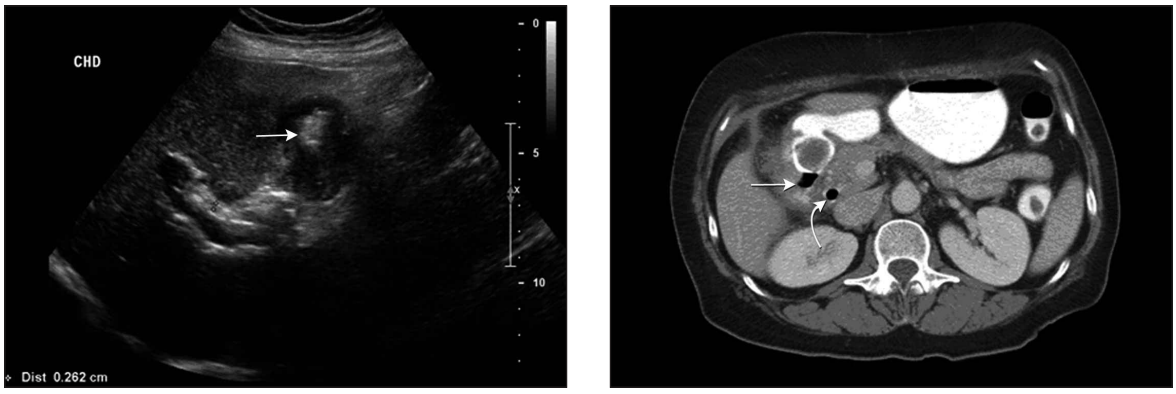


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Figure 17. Gallstone ileus. **A**, Sonogram showing a reverberation artifact (arrow) indicating air within the gallbladder fossa. **B**, Computed tomogram showing air in the gallbladder lumen (arrow) and extending into the common bile duct (curved arrow). The patient had a small-bowel obstruction, and a gallstone impacted at the ileocecal valve was identified (not shown).

Most obstructions occur at the distal duct from common bile duct stones, pancreatitis, or pancreatic cancer. Between the pancreas and the porta hepatis, adenopathy, primary biliary ductal carcinoma, and a mass in the duodenum or colon may be potential causes (Figure 18). Once extrahepatic obstruction becomes severe, both intrahepatic and extrahepatic dilatation may be seen (Figure 19).

Intrahepatic bile ducts are 2 mm or smaller at the porta hepatis and no more than 40% of the diameter of the accompanying portal vein. Intrahepatic biliary dilatation can be diagnosed by irregular angular branching, a central stellate configuration, and acoustic enhancement posterior to the ducts (Figure 20). Obstructions causing intrahepatic biliary dilatation occur at the level of the porta hepatis or above, with potential causes including cholangiocarcinoma, hepatoma, strictures, and invasive gallbladder cancer.

Sonography is not the study of choice for evaluation of choledocholithiasis because of its limited sensitivity; however, it is highly specific if a stone is identified (Figure 21). If choledocholithiasis is suspected but cannot be confirmed by sonography, magnetic resonance cholangiopancreatography is highly sensitive and specific.

Liver

The range of liver diseases visible on RUQ sonography is extensive and beyond the scope of this review. In the acute setting, findings may be grossly subdivided into infections, neoplasms, and cirrhosis and its complications.

Figure 18. Dilated common bile duct (arrow) without intrahepatic biliary dilatation.

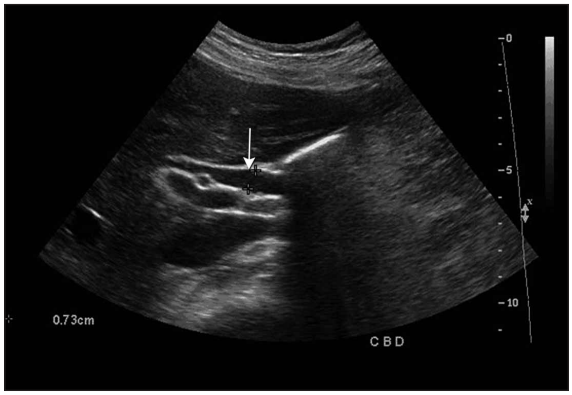
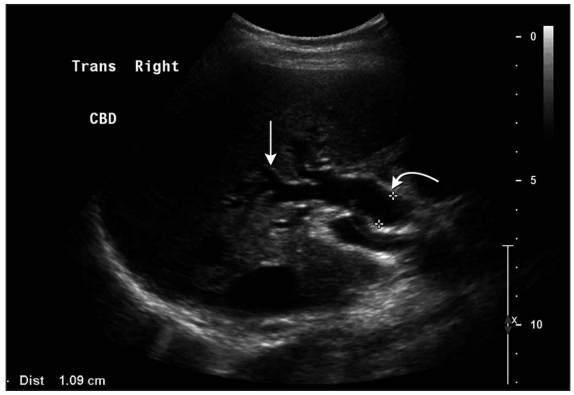


Figure 19. Intrahepatic and extrahepatic biliary dilatation: sonogram of the liver showing severely dilated intrahepatic (arrow) and extrahepatic (curved arrow) bile ducts.



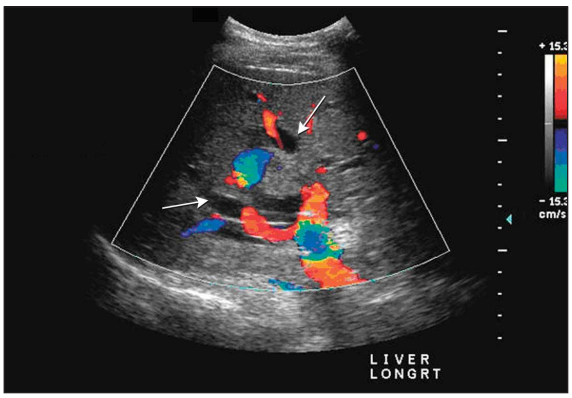


Figure 20. Intrahepatic biliary dilatation: color Doppler image documenting that these anechoic spaces are nonvascular structures (arrows).

Liver Infections

Acute infections of the liver may certainly be a cause of RUQ pain, often associated with systemic symptoms such as nausea and vomiting. The diagnostic considerations depend on whether the pattern is diffuse or focal. The most common diffuse infection encountered in the acute setting is viral hepatitis. In the setting of acute viral hepatitis, sonography may show diffusely decreased liver echogenicity, with a relative increase in the echogenicity of the portal triads, producing a "starry sky" appearance (Figure 22). Although most commonly described in cases of acute hepatitis, this starry sky appearance is nonspecific and has also been described in the setting of leukemia, Burkitt lymphoma, toxic shock syndrome, fasting liver, and severe hepatic congestion.[15]

Focal infections that present acutely include liver abscesses, which are most commonly the result of hematogenous spreading of an infection via the portal vein (48%), with the second most common source being an ascending infection via involvement of the biliary tree (28%). Sonography is the diagnostic imaging modality of choice in these patients.[16] In this example of a liver abscess (Figure 23), sonography of the right lobe of the liver shows a large complex heterogeneous lesion. Computed tomography at the same level shows a large complex fluid collection within the liver. This liver abscess was an ascending infection from perforated appendicitis.

Liver Neoplasms

Primary and secondary hepatic neoplasms are infrequent causes of acute symptoms but may be identified on urgent RUQ sonograms obtained for other reasons. Common primary malignant tumors include hepatocellular carcinoma (Figure 24) and cholangiocarcinoma (Figure 25). Imaging features are highly variable, as these lesions may be echogenic, hypoechoic, or isoechoic to liver parenchyma. Additional areas of necrosis and hemorrhage may cause a heterogeneous appearance. The most common neoplasms are metastatic lesions (Figure 26), followed by benign tumors such as hemangioma and the more rare hepatic adenoma (Figure 27).

Figure 21. Choledocholithiasis. **A**, Sonogram showing a large echogenic stone (arrow) present within the common bile duct, producing proximal biliary dilatation. **B**, Computed tomogram showing a large stone in the common bile duct (arrow). Central density is seen in the common bile duct, surrounded by a rim of low-attenuation bile. This is known as the target sign.

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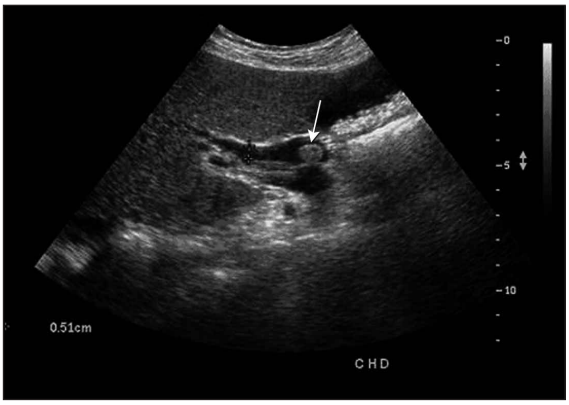

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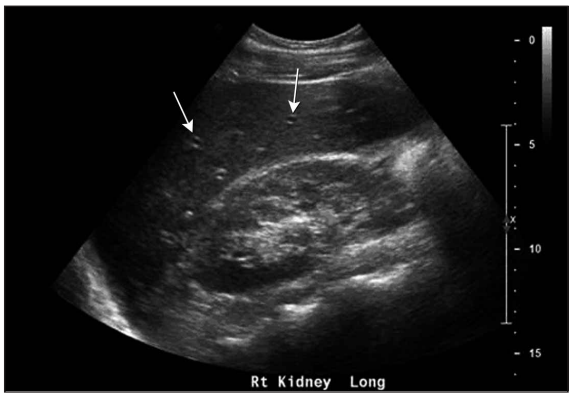

Figure 22. Acute hepatitis: hypoechoic liver with the same echogenicity as the right kidney. There is relative prominence of the portal triads (arrows), giving a starry sky appearance.

Cirrhosis and Associated Vascular Abnormalities of the Liver

In the setting of cirrhosis, the liver parenchyma may appear relatively echogenic, with loss of definition of the portal triads. Surface nodularity can best be seen where the liver interfaces with structures that are anechoic (ascites) or echogenic (such as perihepatic fat). In the absence of ascites, coarsening and nodularity are useful signs of cirrhosis (Figure 28).

In addition to gray scale evaluation of the liver parenchyma, Doppler evaluation of the hepatic vasculature can yield valuable diagnostic information in patients with suspected cirrhosis. In the setting of portal hypertension, portal flow decreases, whereas hepatic arterial flow increases to compensate. However, once intrahepatic resistance in the sinusoids and central veins becomes too great for high-pressure arterial flow, some of the arterial flow gets diverted into the portal system through microcollaterals in peribiliary plexuses. The easiest collateral to detect sonographically is the umbilical vein (Figure 29).[3]

Color Doppler evaluation of the portal vein itself is included in all RUQ sonographic examinations in our institution. Unsuspected portal vein disease may be shown, such as portal vein thrombosis, which may be related to bland thrombosis, or a tumor thrombus (Figure 30). Once portal vein thrombosis becomes chronic, cavernization (Figure 31) may be seen, with formation of extensive collaterals via the vasa vasorum of the portal vein.

In addition, apparent gallbladder wall thickening can be mimicked by gallbladder wall varices in a patient with portal hypertension. This can be readily distinguished with Doppler imaging (Figure 32).

Pancreas

In general, sonography plays two major roles in acute imaging of the pancreas: evaluating for gallstones and biliary obstruction as a cause of acute pancreatitis and assessing complications of chronic pancreatitis. The features of pancreatic enlargement and decreased echogenicity relative to the liver are the hallmarks of acute pancreatitis on sonography. When acute pancreatitis is suspected to be related to stone disease,

Figure 23. Liver abscess. **A**, Sonogram showing a heterogeneous appearance of the entire right lobe of the liver (arrow) in a patient with perforated appendicitis and sepsis. **B**, Computed tomogram from the patient in Figure 18 showing an abscess (arrow).

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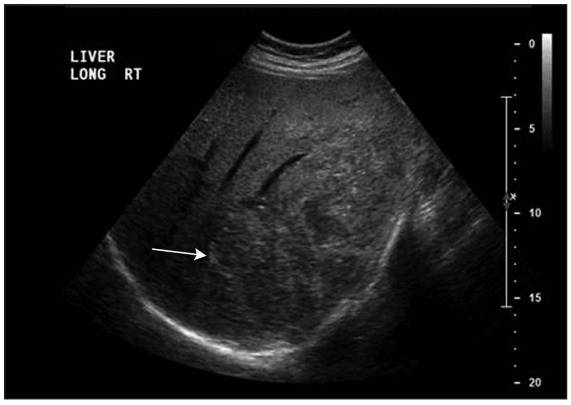

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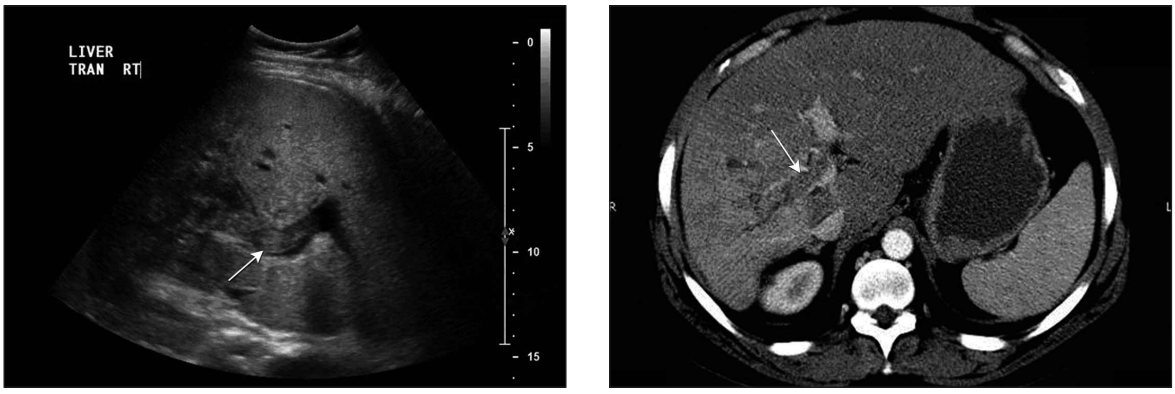

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Figure 24. Large hepatocellular carcinoma. **A**, Sonogram showing the right lobe of the liver with invasion of the right portal vein (arrow) and a tumor thrombus. **B**, Contrast-enhanced CT from the same patient showing a filling defect in the right portal vein and its branches (arrow) and a transient hepatic attenuation difference.

RUQ sonography may help determine appropriate management, be it preoperative endoscopic retrograde cholangiopancreatography or cholecystectomy (Figure 33). However, CT remains the primary modality for identifying necrotic parenchyma and extraparenchymal involvement.

Sonographic findings of chronic pancreatitis (Figure 34) consist of pancreatic calcification, changes in the size and echo texture of the pancreas, beading of the pancreatic duct (Figure 35), and pseudocyst formation. Pancreatic pseudocysts are reported in 25% to 40% of chronic pancreatitis cases. Pancreatic neoplasms and masses may be incidentally noted; however, a cross-sectional imaging study will subsequently be necessary for full characterization.

Right Adrenal Gland

The right adrenal gland is generally seen when it is enlarged, as with a mass (Figure 36) or in adrenal hemorrhage. In the example shown, the patient went to the emergency department with RUQ pain, and sonography showed a large heterogeneous cystic mass with a well-defined echogenic capsule. The heterogeneity is secondary to necrosis and hemorrhage in this complex tumor. Although various sonographic findings may suggest the etiology of an adrenal mass, such as a speed propagation artifact in adrenal myelolipoma, a full discussion of these imaging features is beyond the scope of this review.

Figure 25. Klatskin tumor. **A**, Sonogram showing a central cholangiocarcinoma (Klatskin tumor) at the porta hepatis (arrow) with dilated and tortuous intrahepatic bile ducts. **B**, Computed tomogram from the same patient showing the same findings.

A B

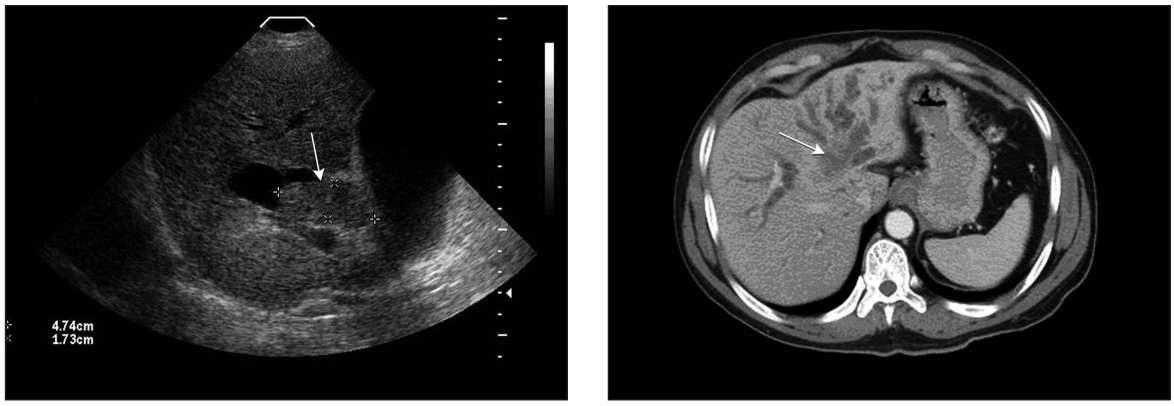


Figure 26. Liver metastasis: several necrotic heterogeneous liver masses (arrows) in a patient with known breast carcinoma.

Kidney

Sonographic evaluation of the right kidney can identify a range of acute and chronic pathologic conditions. Echogenic foci on sonography may be caused by renal stones (Figure 37), with resultant hydronephrosis (Figure 38). Renal calculi are generally seen as echogenic foci with sharp distal acoustic shadowing; however, very small stones may appear as echogenic foci without appreciable shadowing and may be hard to separate from the echogenic renal sinus.

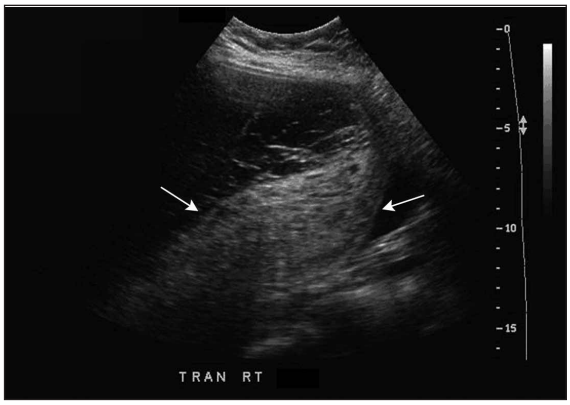
On sonography, nephrocalcinosis may also present as multiple echogenic foci with shadowing in the region of the pyramids (Figure 39). It is seen most commonly in the setting of hyperparathyroidism, renal tubular acidosis, and a medullary sponge kidney.

Subacute or chronic findings may include increased renal cortical echogenicity, which may be seen in medical renal disease (Figure 40), including diabetes, hypertension, and HIV/acquired immunodeficiency syndrome nephropathy, among others. A renal mass or complex cyst may also be incidentally shown, the features of which are beyond the scope of this review of urgent RUQ sonography. If a mass is identified, full sonographic evaluation of the left kidney is required. The above findings, however, will generally not be associated with acute symptoms, and the search must be continued for the acute process.

Although sonographic findings may be normal in the setting of pyelonephritis, enlarged and edematous kidneys are suggestive of the diagnosis with the appropriate clinical findings. If acute pyelonephritis is clinically suspected, a careful search must be undertaken for possible complications. Fluid collections around the kidney may be seen in the setting of pericalyceal rupture or an abscess, and shadowing from air within the collecting system is highly suggestive of emphysematous pyelitis (Figure 41) or emphysematous pyelonephritis. Emphysematous pyelitis is a condition in which gas forms in the collecting system but remains separate from the renal parenchyma (as seen in emphysematous pyelonephritis). It may be difficult sonographically, however, to discern whether the gas is confined to the collecting system or involves parenchyma, and CT may be helpful for making this determination.

Figure 27. Hepatic adenoma. **A**, Sonogram showing a complex fluid collection with internal septations (arrows) in the right lobe of the liver from hemorrhage within a hepatic adenoma. **B**, Computed tomogram from the same patient showing hemorrhage (arrow) within the large hepatic adenoma.

A



B

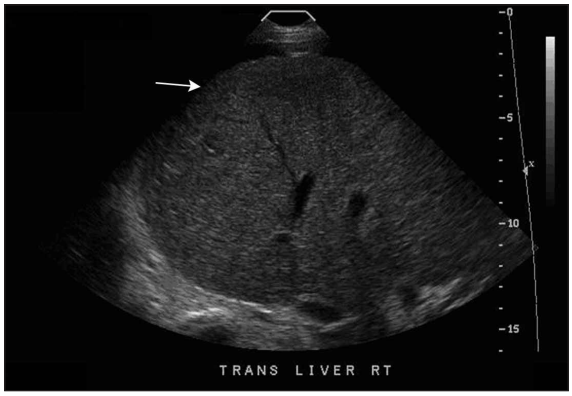


Figure 28. Dense liver with loss of definition of the portal triads and a nodular surface (arrow) in cirrhosis.

Inferior Vena Cava

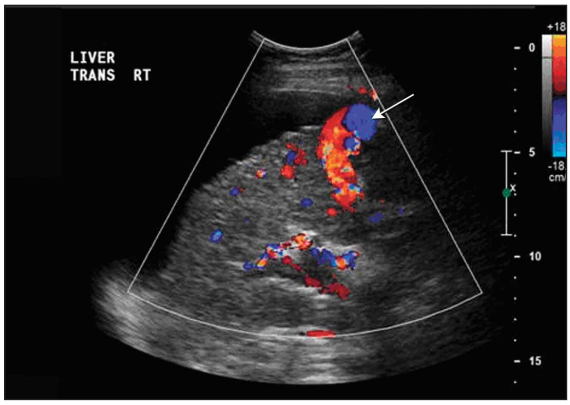
The IVC is also included as part of our standardized RUQ sonographic examination and should be inspected carefully for abnormalities. In this case, an IVC thrombus appears as an intraluminal filling defect that expands the lumen of the intrahepatic portion of the IVC. In the case shown here, a heterogeneous mass seen in the liver has produced extrinsic compression on the IVC with a resultant thrombus (Figure 42). A thrombus in the IVC may also be the result of extension from a thrombus in another vein in the pelvis, lower limb, liver, or kidney.

Conclusions

Right upper quadrant sonography is the first line of imaging in patients with signs and symptoms of hepatic, gallbladder, or biliary disease as well as RUQ pain. Awareness of the range of conditions that may be encountered, as well as the typical imaging characteristics of several common incidental findings, will allow the radiologist to provide an appropriate diagnosis or make appropriate additional imaging recommendations.

Figure 29. Recannalization of the umbilical vein. **A**, Sonogram showing recannalization (arrow) extending along the falciform ligament to the midline. **B**, Computed tomogram from the same patient showing contrast filling the recannalized umbilical vein (arrow) extending along the falciform ligament to the midline. A nodular shrunken liver is present.

A



B

Figure 30. Portal vein thrombosis with absent flow in the main portal vein with echogenic intraluminal thrombus (arrows).

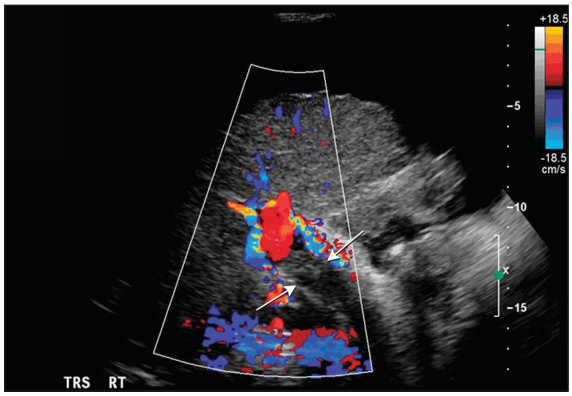


Figure 31. Portal vein cavernization. **A**, Color Doppler image showing absent flow in the main portal vein (arrow) and multiple collaterals producing cavernization of the portal vein (curved arrows). **B**, Contrast-enhanced CT showing cavernization (arrow).

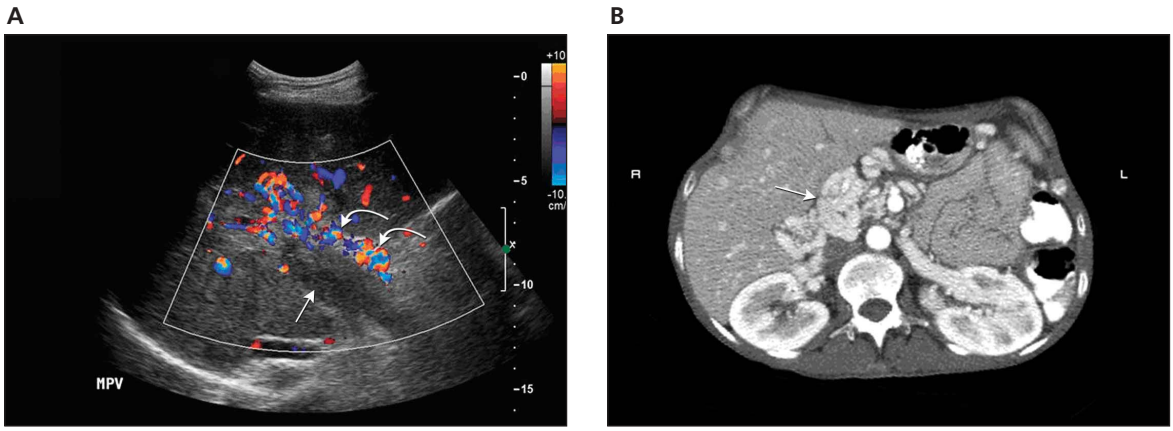


Figure 32. Gallbladder wall varices: color Doppler image showing multiple collaterals in the gallbladder wall (arrows).

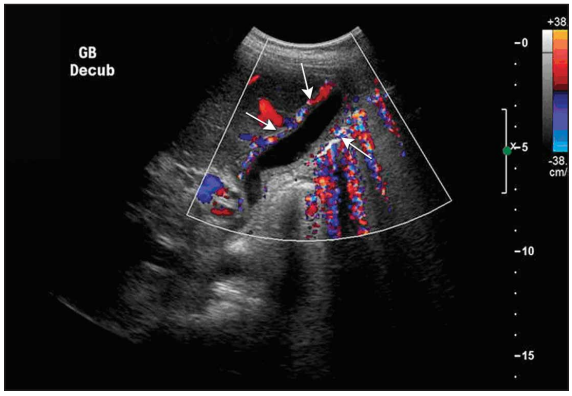


Figure 33. Acute pancreatitis. **A**, Sonogram showing a diffusely hypoechoic pancreas (arrow) with peripancreatic fluid (curved arrow). **B**, Computed tomogram showing peripancreatic phlegmon and fluid (arrow).

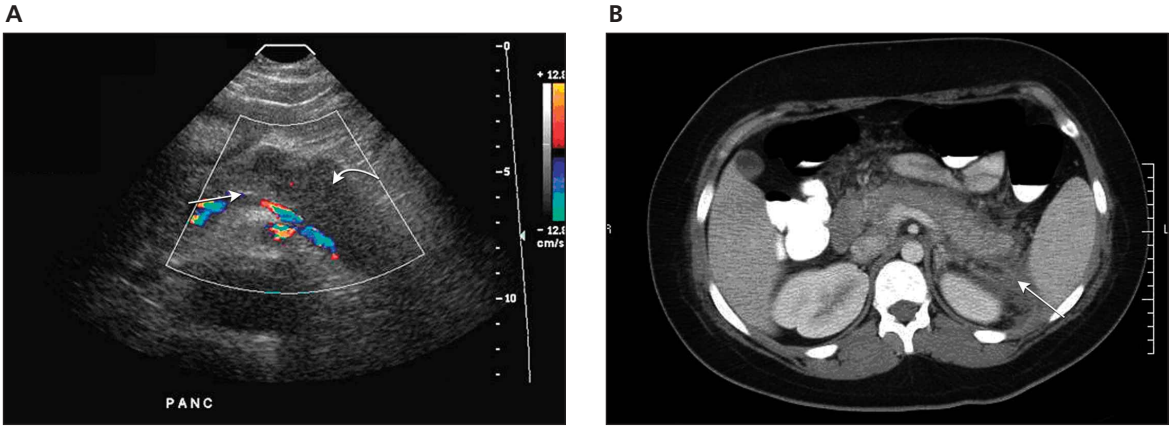


Figure 34. Chronic pancreatitis. **A**, Transverse view showing multiple calcifications (arrows) and pseudocyst formation (curved arrow). **B**, Computed tomogram from the same patient showing pseudocyst formation (curved arrows) and calcifications (arrow).

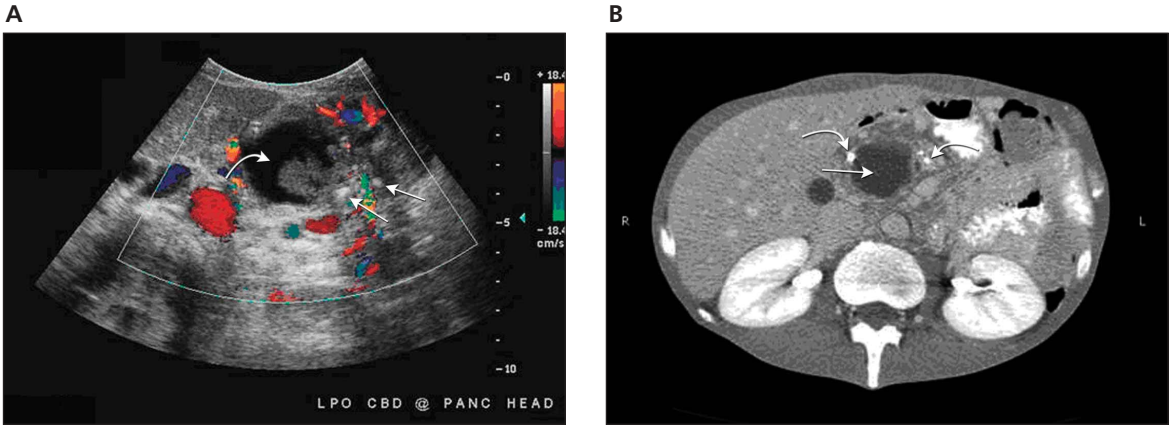


Figure 35. Chronic pancreatitis. **A**, Sonogram showing a dilated pancreatic duct (arrow) and dilated common bile duct (curved arrow) in the head of the pancreas. **B**, Computed tomogram from the same patient showing a beaded appearance (arrows) of the pancreatic duct and multiple pancreatic calcifications (curved arrow).

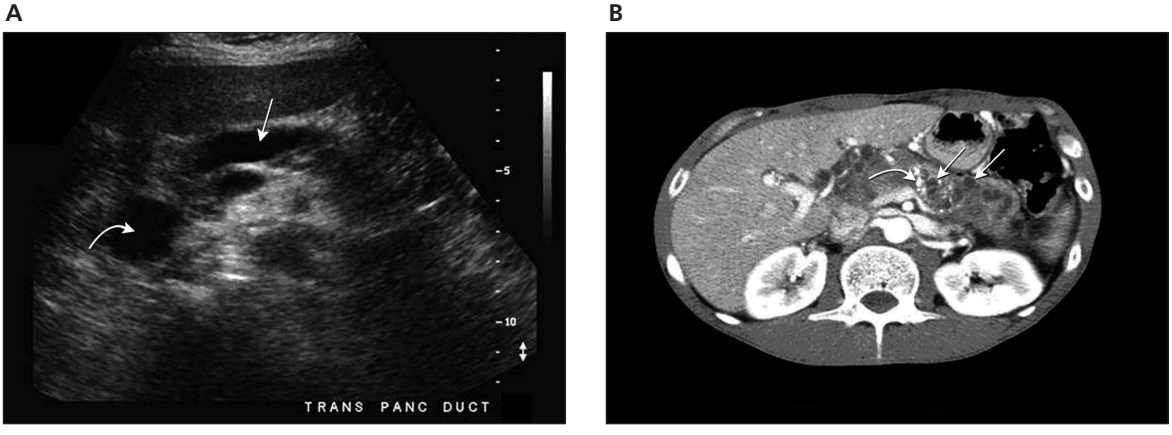


Figure 36. Right adrenal mass. **A**, Sonogram showing a complex mass with cystic changes in the right adrenal gland (arrows). **B**, Computed tomogram showing the mass (arrows).

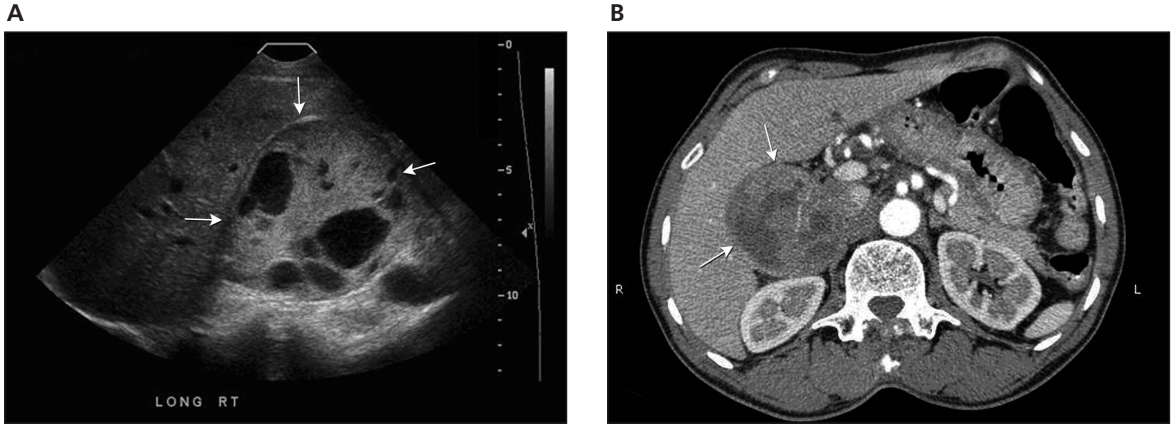


Figure 37. Dense echogenic renal calculus (arrow) with posterior acoustic shadowing.

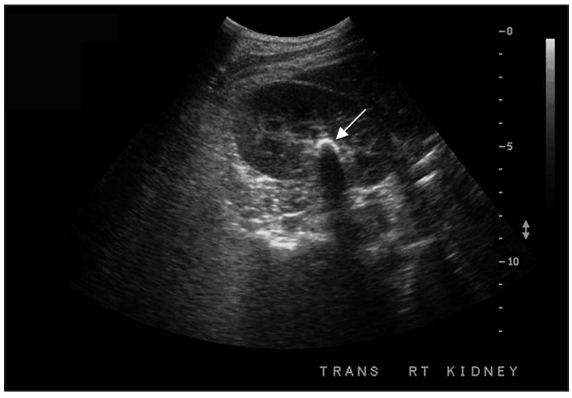


Figure 38. Hydronephrosis of the right kidney with a proximal ureteral stone (arrow).

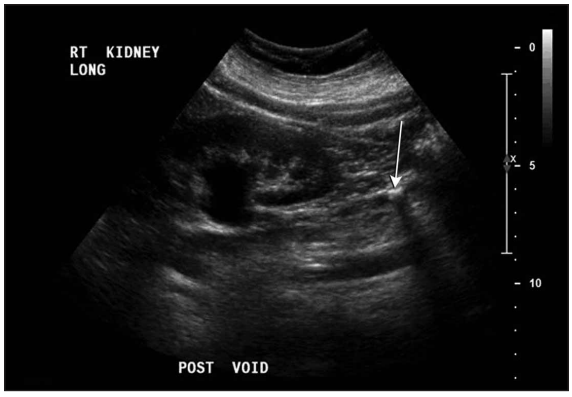


Figure 39. Nephrocalcinosis. **A**, Sonogram showing multiple medullary calcifications (arrows). **B**, Computed tomogram showing the calcifications (arrows).

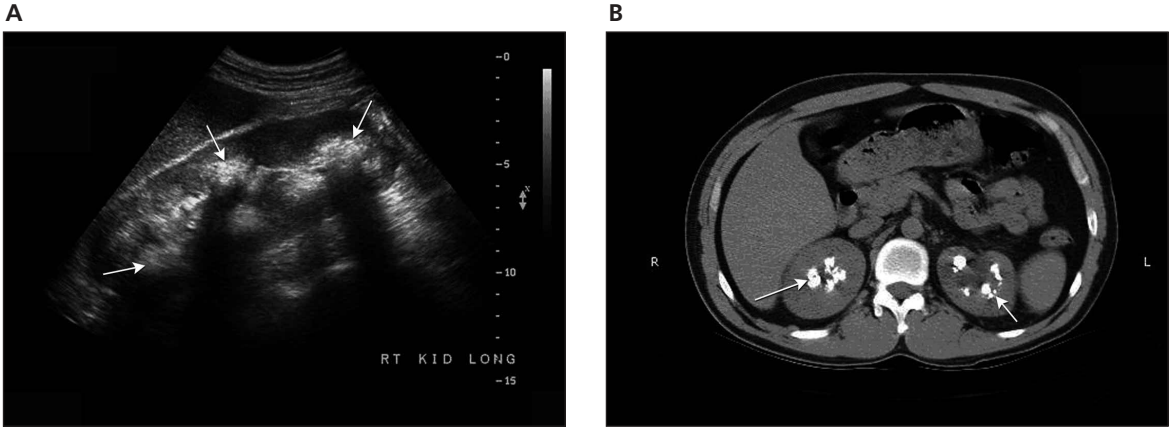


Figure 40. Medical renal disease. Increased renal cortical echogenicity (arrow) in HIV/acquired immunodeficiency syndrome nephropathy.

Figure 41. Emphysematous pyelitis. **A**, Sonogram showing dirty shadowing from air (arrows). **B**, Computed tomogram showing air within the right collecting system (arrows).

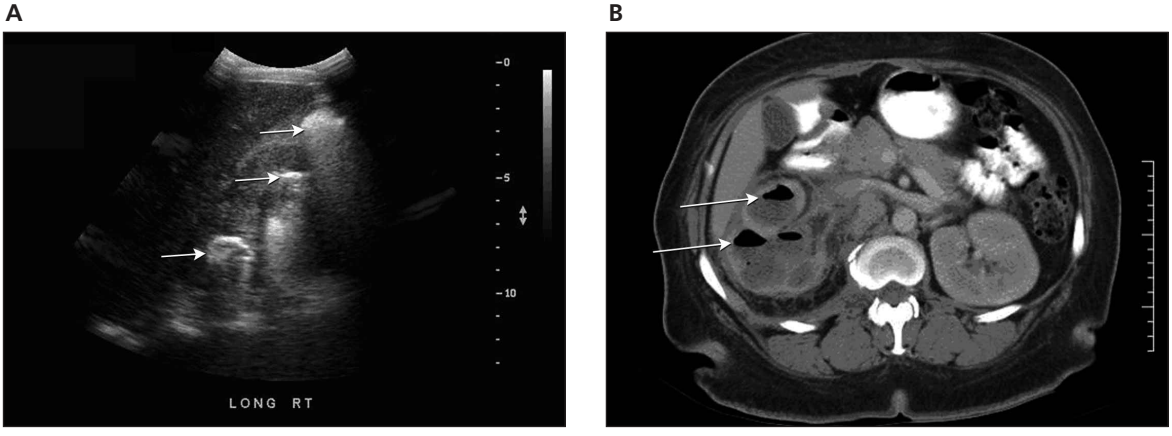
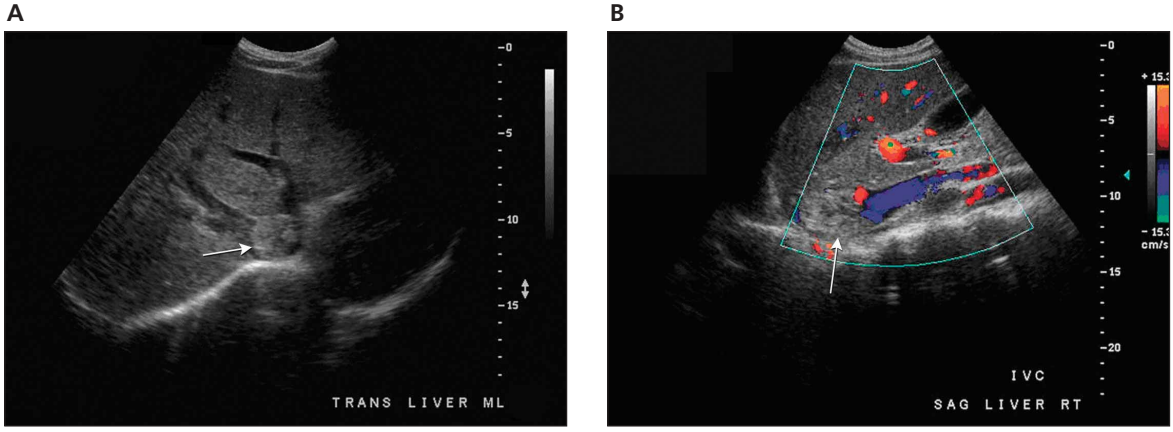


Figure 42. Inferior vena cava thrombus. **A**, Transverse view showing an echogenic filling defect within the IVC (arrow) at the confluence of the hepatic veins. **B**, Echogenic filling defect with absence of color within the IVC (arrow) at the confluence of the hepatic veins.



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