Ultrasonography of the Acute Abdomen

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For many years, ultrasonography has been considered to be one of the most valuable imaging techniques for evaluation of the abdominal cavity and its organs. In most cases, abdominal ultrasonography helps obtain information that leads to a definitive diagnosis. Ultrasonography is also valuable to narrow the list of differential diagnoses obtained with other diagnostic techniques. This article discusses the role of ultrasound for the diagnosis of the most common diseases that can produce clinical signs of acute abdominal pain. Abdominal organs that can be evaluated using ultrasound include the liver, biliary system, pancreas, stomach, small intestine, kidney, urinary bladder, uterus, and prostate. Pathologies of the abdominal cavity and retroperitoneal space can be also diagnosed with ultrasonography. Interventional ultrasound techniques are useful to either assist in getting the definitive diagnosis or to treat certain pathologic conditions.

Acute abdomen is considered an emergency in veterinary medicine. In general, acute abdomen is a medical term that defines the sudden onset of abdominal pain. Other clinical signs may be present in addition to abdominal pain, including abdominal distention, vomiting, diarrhea, anorexia, lethargy, postural and gait changes, and shock.[1,2] Accurate and prompt diagnosis assures successful management and implementation of appropriate therapy. Diagnostic imaging tools, such as radiology and ultrasonography, can assist in the diagnosis and treatment of acute abdomen. The causes of acute abdomen in the small animal patient have been reviewed already.[1-3]

The physical principles of ultrasonography also have been reviewed previously by others.[4-6] An ultrasound image is formed when the ultrasound waves directed into the patient are reflected by the different abdominal organs. The ultrasound beam can be reflected, attenuated, or transmitted, depending on the internal architecture of the organ. The ultrasound beam is reflected by very dense tissues or structures (calculi, fibrous or sclerotic tissue, and bone), forming very bright, hyperechoic images. The ultrasound beam is partially reflected, partially transmitted, and partially attenuated by soft tissues (parenchymal organs such as liver, spleen, and kidneys), forming hypoechoic images that appear as different shadows or shades of gray. Finally, the ultrasound beam is completely transmitted by fluid-filled structures forming anechoic black areas.

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The most common artifacts in ultrasound are through transmission and shadowing. Through transmission artifacts originate when the ultrasound beam interacts with a fluid-filled structure (Fig 1). The ultrasound beam is not attenuated by fluids. Rather, the beam is transmitted. Then the ultrasound beam interacts with the tissue located underneath the fluid-filled structure and it is reflected, producing echoes of high intensity that appear as relatively hyperechoic areas. Shadowing artifacts are produced by highly reflective tissues (Fig 2). The ultrasound beam is completely reflected back to the transducer, such that no ultrasound beam is transmitted to the tissues lying beneath the highly reflecting tissue. Because there are no echoes coming back to the transducer to produce a signal, this area appears completely anechoic.

Organs located underneath highly reflected tissues may not be seen at all. The goal of this study is to review the role of ultrasonography in the diagnosis of acute abdomen in the small animal patient.[4-6]

Hepatobiliary System

Techniques for performing an ultrasound examination of the hepatobiliary system and its normal ultrasonographic appearance have been well documented.[7] The hepatic parenchyma normally appears as homogenous and hypoechoic in nature.[7,8] The hepatic veins are differentiated from portal veins because portal veins have hyperechoic walls, while the hepatic veins do not. The gallbladder can be visualized as an anechoic ovoid structure producing a through transmission artifact. Sediment appears as echogenic material within the gallbladder and is a normal finding in dogs and cats. Hepatomegaly is difficult to diagnose with ultrasound. Extension of the left aspect of the liver ventral to the stomach can be assessed for indications of hepatomegaly. The liver lobe in that area can be also evaluated for changes in its margins, such as having rounded borders. The echogenicity of the liver parenchyma should be compared with the echogenicity of the spleen and renal cortex. Normally, the liver should be slightly more echogenic or isoechoic (same echogenicity) when compared with the renal cortex; and should be hypoechoic compared with the splenic parenchyma. Overall echogenicity of the liver may be normal, or may be decreased with increased visualization of the portal veins in cases of acute hepatitis and severe suppurative hepatitis.[7-9] However, a similar ultrasonographic appearance may be present in dogs with lymphoma, leukemia, and amyloidosis. Passive venous congestion caused by heart disease may also cause decreased echogenicity with engorgement of the hepatic veins. Portal hypertension is most commonly seen in patients with chronic hepatitis and hepatic cirrhosis.[7-9] This pathological change also has been reported in human patients and rat animal models with severe acute hepatitis.[10,11] The proposed mechanism for portal hypertension in acute hepatitis is that the

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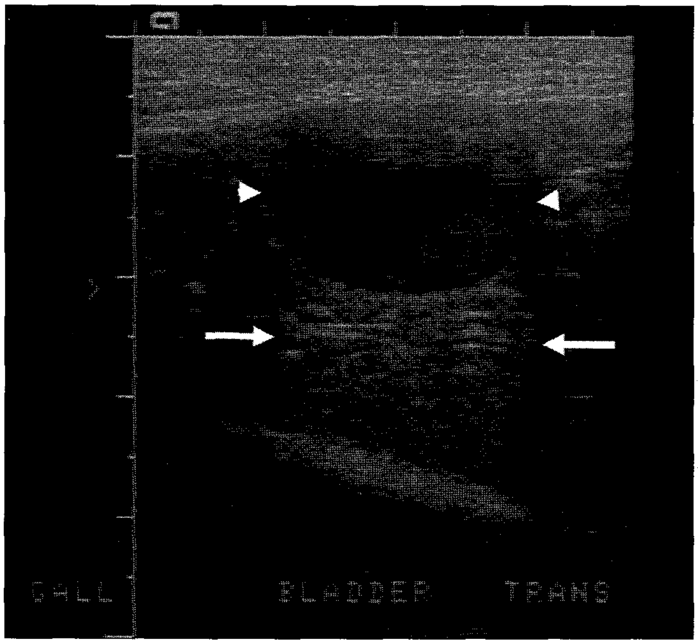

Fig 1. Ultrasonographic image of the liver and gall bladder (arrowheads). Through transmission artifact (arrows) is produced by the gall bladder as a fluid-filled structure.

portal vein and hepatic arteries compensate in an attempt to supply increased blood flow to the inflamed liver.

Hepatic abscess formation is not a very common pathologic finding in veterinary medicine. Abdominal radiographs may reveal hepatomegaly, decreased abdominal detail, or evidence of a liver mass. The ultrasonographic pattern of abscesses within the hepatic parenchyma is extremely variable. The characteristic pattern depends on the age of the abscess, the presence of central area of necrosis, and the content of the abscess. A liver abscess may appear anechoic, hypoechoic, hyperechoic, or isoechoic. It has been reported that the most common ultrasonographic feature of hepatic abscess is the visualization of a fairly rounded well-circumscribed area with hyperechoic margins surrounding a hyperechoic or anechoic central zone. Early changes are characterized by the presence of a hypoechoic area with an anechoic central area and a thin hypoechoic rim (Fig 3). A well-formed abscess has been described as a heteroechoic

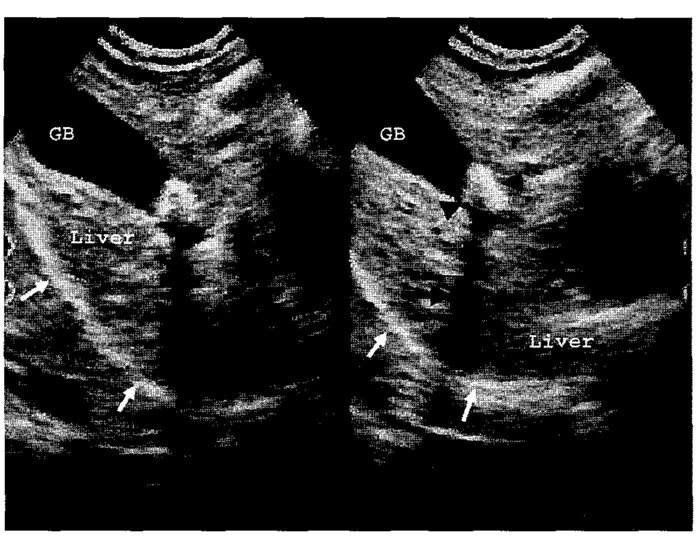

Fig 2. Ultrasonography of the liver and gall bladder (GB). Shadowing artifact (black arrows) is produced by a calculus in the neck of the GB (arrowheads). The diaphragm can be seen (white arrows).

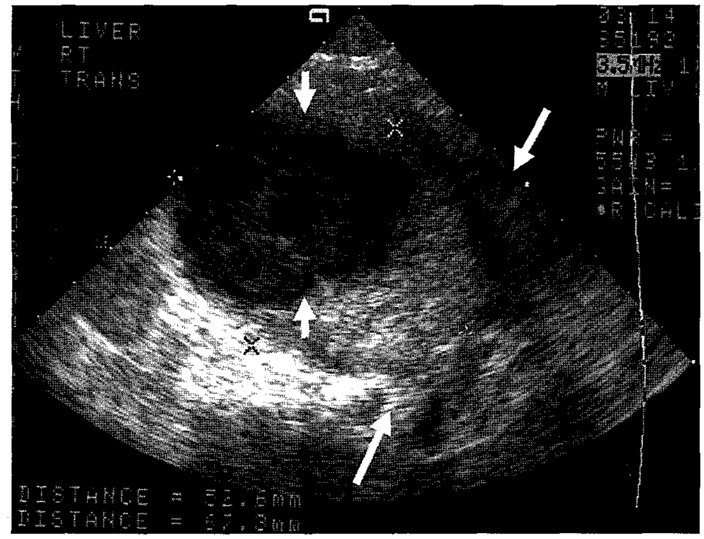

Fig 3. Ultrasonographic image of the right liver in sagittal plane (large arrows). The hypoechoic irregular-shaped structure seen in the liver parenchyma represents the sonographic evidence of abscess.

mass with a hyperechoic rim with either a hypoechoic or anechoic center. Through transmission artifact may be observed depending on the content of the abscess and whether liquefaction necrosis is present. The presence of gas caused by gas-producing bacteria will produce hyperechoic pattern that varies from foci that appear diffusely hyperechoic or may appear as multiple hyperechoic areas. The history, clinical signs, and serum biochemistry profiles are important factors to use in conjunction with ultrasonographic findings to aid in the diagnosis of hepatic abscess. Correlating clinical findings with sonographic findings that suggest a liver abscess is recommended because similar sonographic changes may be observed with other hepatic lesions, including neoplasia, nodular hyperplasia, hematomas, sterile abscess, and granulomas. Ultrasound-guided aspiration and monitoring after treatment by using ultrasonography are also possible.[7,8]

Ultrasonographic findings of liver lobe torsion have been described in a dog as evidence of a heteroechoic soft tissue density with a hyperechoic center (indicating the presence of gas). At surgery, torsion of the papillary process of the caudate lobe of the liver was found.[12]

Biliary System

Diseases of the biliary system can also cause clinical signs of acute abdominal pain. Ultrasonography is a useful tool to evaluate the gallbladder and the common bile duct.[7,13,14] Acute cholecystitis may be characterized by thickening of the gallbladder wall (Fig 4).[7,13] Cholelithiasis and biliary sludge may be present. A patient may exhibit the Murphy sign, or pain elicited during ultrasonographic examination of the gallbladder. Visualization of reverberation and gallbladder wall thickening may be observed in dogs with emphysematous cholecystitis. Hyperechoic areas within the lumen or wall of the gallbladder may also be observed. Gallbladder mucoceles have a very characteristic ultrasonographic pattern, as evidence by a striated appearance of sludge accumulation within an apparent intraluminal mass (Fig 5). The sludge does not move during scanning of the patient in a standing position or during mild agitation during the ultrasonographic examination. The gallbladder usually is

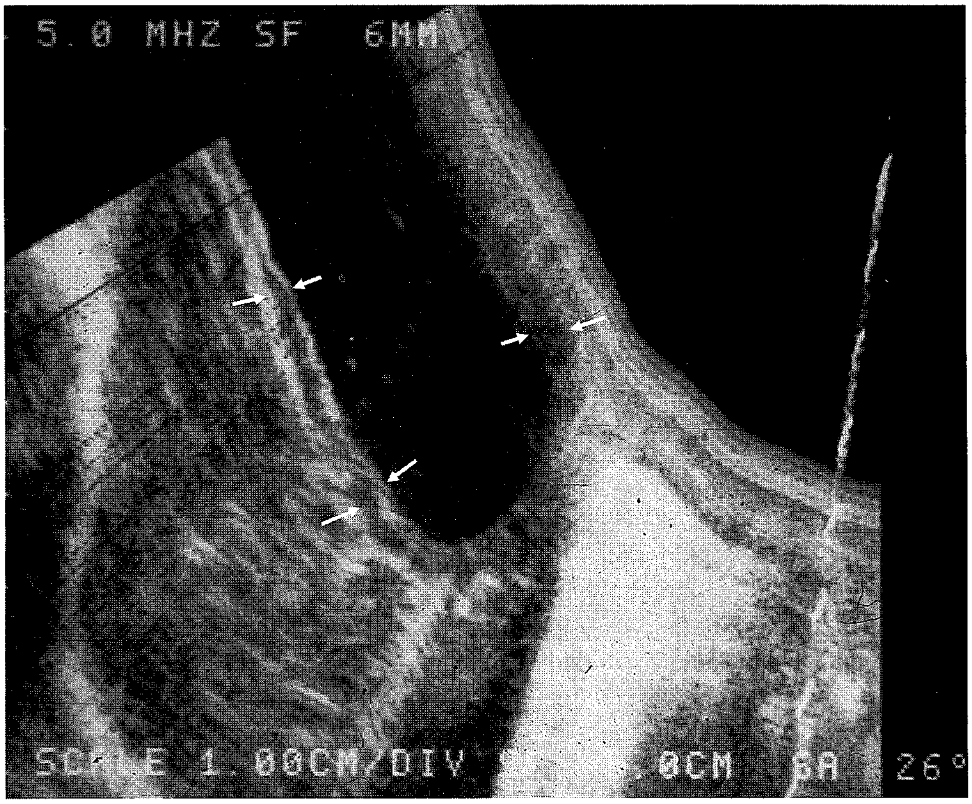

Fig 4. Ultrasonographic image of liver and gall bladder. The gall bladder wall is thickened (arrows).

very distended.[7] Cholangiohepatitis syndrome is characterized by decreased echogenicity of the hepatic parenchyma, increased visualization of the portal veins, and abnormal gallbladder and bile ducts.[7,15]

Biliary tract obstruction can be identified ultrasonographically by the presence of a dilated gallbladder and common bile duct (Fig 6). Dilation of the extrahepatic bile duct also may be identified. With persistent biliary obstruction, cystic-like dilation of the intrahepatic bile ducts may be present. Extrahepatic biliary obstruction may be observed in patients with pancreatic and duodenal tumors, hepatic abscesses, and portal lymphadenopathy.[14] Obstructive and nonobstructive biliary disease can be further documented by measuring the gallbladder emptying after injecting synthetic cholecystokinin (0.04 μg/kg) intravenously. Gallbladder emptying will be rapidly induced in unaffected dogs or dogs without biliary tract obstruction.[16] Normal percentage of emptying has been reported as 40% within 1 hour (maximum response 5 to 20 minutes) after the injection of cholecystokinin in completely normal dogs and dogs with nonobstructive liver disease and 20% in dogs with biliary obstruction.[16] No complications were observed performing this technique.

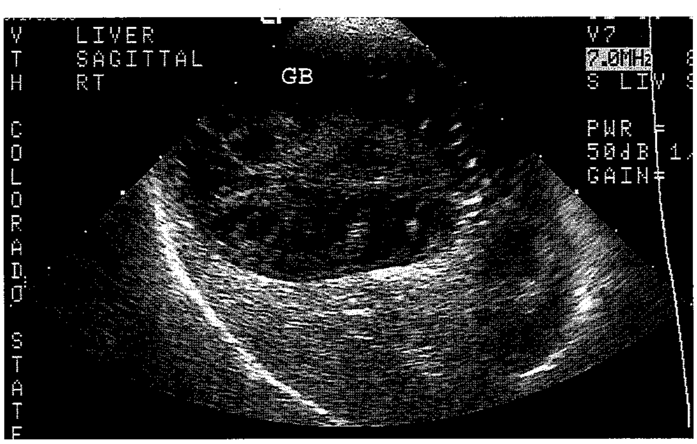

Fig 5. Sagittal plane ultrasonographic image of the gall bladder with mucocele (see the text for detailed description).

Choleliths are easily identified on the ultrasonographic examination, and appear as a hyperechoic focus or multiple hyperechoic foci with a strong shadowing artifact (Fig 7).[7] A characteristic ultrasonographic feature of cholecystitis is thickening of the gallbladder wall.[17] The gallbladder often appears as hypoechoic, hyperechoic, or hyperechoic with surrounding rim of edema. This is called a double wall sign.[17] Ultrasound-guided cholecystocentesis is an interventional ultrasound technique to obtain a sample of bile for culture, bacterial susceptibility testing, and cytological examination. Ultrasound-guided cholecystocentesis has been reported to be very useful in confirming a diagnosis of bacterial cholecystitis.[17] Sedation is recommended before attempting this diagnostic procedure. No risk has been reported; however, potential complications include bile peritonitis caused by bile leakage. The author performed this technique in a cat at the Ultrasound Service of the Veterinary Teaching Hospital, Colorado State University. No complications were noted by the primary case clinician after the procedure was performed. The diagnosis of bacterial cholecystitis was obtained, and the cat was treated successfully.

Pancreas

Pancreatitis is one of the most common causes of acute abdomen. The right limb of the pancreas is located medial to the duodenum and lateral to the ascending colon (Fig 8). The left limb of the pancreas is located between the caudal aspect of the stomach and the transverse colon. The normal pancreas appears isoechoic or slightly hypoechoic compared with the surrounding mesenteric fat.[18] Ultrasonographic findings consis-

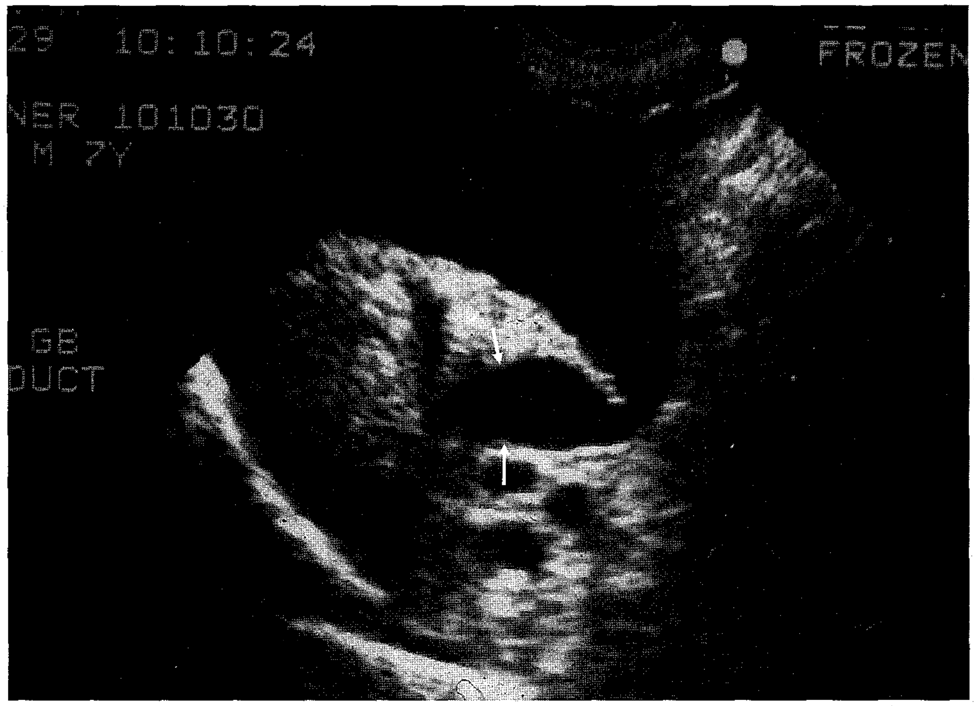

Fig 6. Ultrasonographic image of the liver that shows dilatation of the cystic duct of the gall bladder.

tent with pancreatitis include an enlarged and hypoechoic pancreas. In some cases, an irregular, hypoechoic ill-defined mass located in the pancreatic region may be observed (Fig 9).[19,20] Dilation of the pancreatic duct also may be present (Fig 10).[18] Extrapancreatic sonographic findings include free fluid within the abdomen, small intestinal ileus (especially the duodenum), and irregular, hyperechoic mesenteric fat suggesting saponification with focal peritonitis. Thickening of the walls of the duodenum and stomach along with displacement of both organs may also be observed.[18] Common ultrasonographic changes for fatal acute pancreatitis reported in 70 dogs include a hypoechoic pancreas, hyperechoic peripancreatic tissues, enlarged and irregular pancreas, duodenitis, and extrahepatic biliary obstruction. The gallbladder may be enlarged and the bile duct may appear dilated.[20] In some patients, the pancreas may be ultrasonographically normal; however, in these cases, ultrasonographic changes in the liver, such as hepatic lipidosis and peritoneal effusion, are frequently identified.[7] Inflammatory mass formation affecting the pancreas or peripancreatic tissues secondary to acute pancreatitis has been reported in humans.[21] In humans, pancreatic phlegmon (solid masses as a result of edema, inflammation, and necrosis), pancreatic pseudocysts (accumulation of pancreatic enzymes, necrotic tissue, and hemorrhage surrounded by a capsule formed by granulation and fibrous tissues), and pancreatic abscesses have been reported to be the most common inflammatory masses of the pancreas.[21] A retrospective study in seven dogs that underwent pancreatic mass after acute pancreatitis revealed that the most common finding on surgical exploration was the presence of a

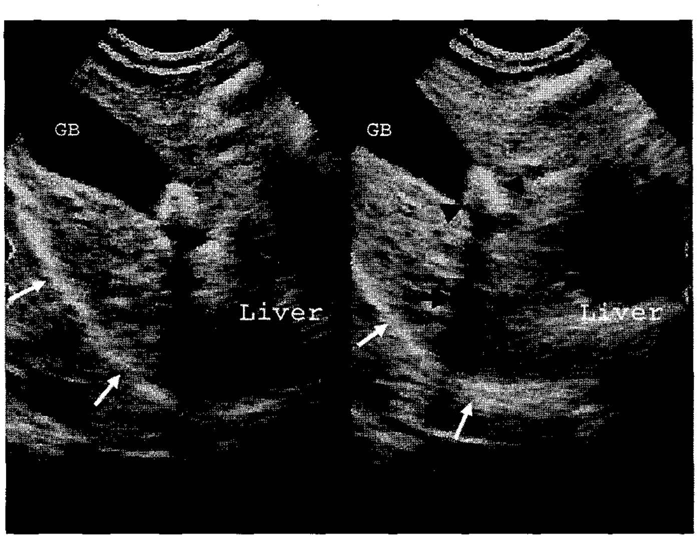

Fig 7. Ultrasonographic image of the liver and gall bladder. A colelith is seen in the neck of the gall bladder (arrowheads). Shadowing artifact is also observed (black arrows). The diaphragm can also be seen (white arrows).

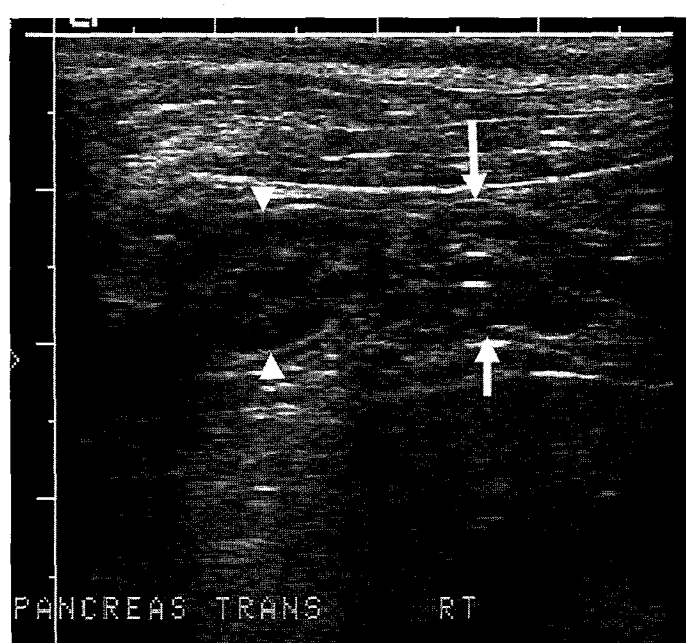

Fig 8. Transverse plane ultrasonography of the normal proximal duodenum (arrowheads) and right limb of the pancreas medial to it (arrows).

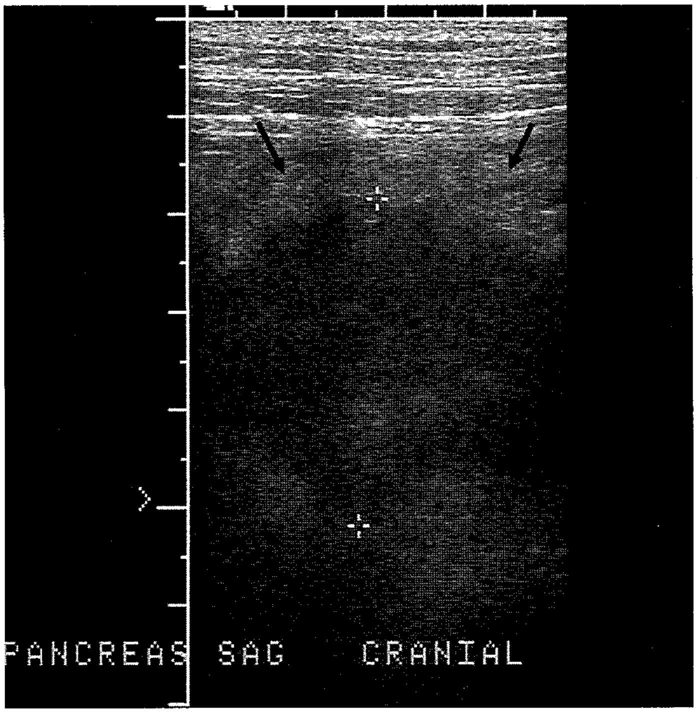

Fig 9. Ultrasonographic image of the right cranial abdomen (right pancreatic area) in a dog with pancreatitis. A hypoechoic mass (between cursors) surrounded by hyperechoic mesenteric fat (saponification) (arrows) is identified medial to the proximal duodenum.

necrotic mass within the area of the pancreas. Only one dog developed a pancreatic abscess.[19] Another common finding was obstruction of the biliary system with peritonitis. Ultrasonographic findings in two dogs in that study included a hyperechoic mass with hypoechoic and anechoic areas in the pancreatic region.[19] Pancreatic abscess in dogs have been ultrasonographically described as hypoechoic masses in the pancreatic area with adjacent fluid accumulation (Fig 11).[22] Pancreatic pseudocysts also have been reported in a dog. Abdominal ultrasonography revealed the mass to appear mostly

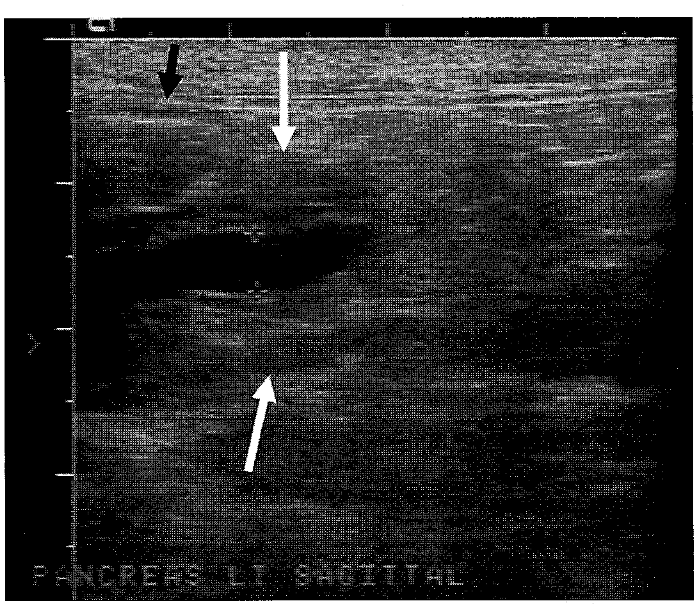

Fig 10. Sagittal sonographic images of a mildly enlarged left limb of the pancreas (white arrows) with dilated pancreatic duct (between cursors). The stomach can be seen (black arrows) ventral and cranial to it.

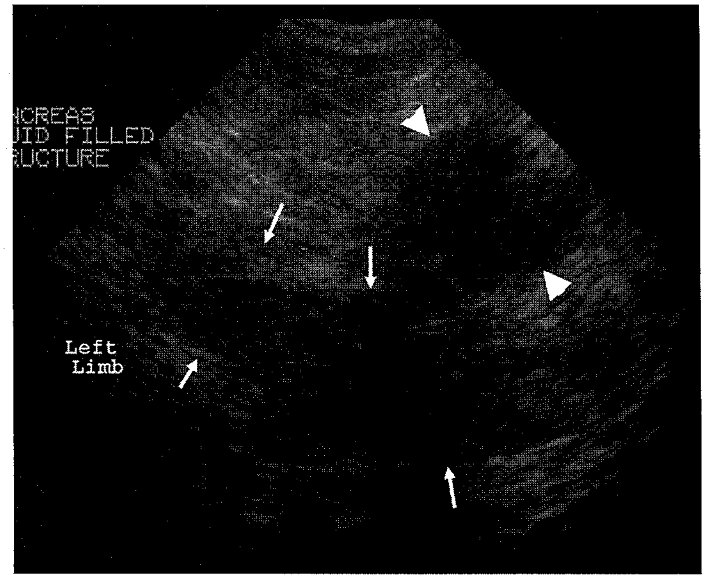

Fig 11. Ultrasonography of the left cranial abdomen in a dog with pain in that region and depression. A pancreatic abscess characterized by a hypoechoic mass (arrowheads) is seen in the left pancreatic region. The left limb of the pancreas is enlarged, hypoechoic and irregular-shaped (arrows) due to pancreatitis. These findings were confirmed on necropsy.

anechoic over hypoechoic in nature, with a small amount of through transmission artifact. Some echoes were also present within the anechoic mass.[23] These sonographic characteristics might be useful to place a pseudocyst first on the list of differential sonographic diagnosis, compared with a pancreatic abscess in dogs with longstanding pancreatic disease. Ultrasound

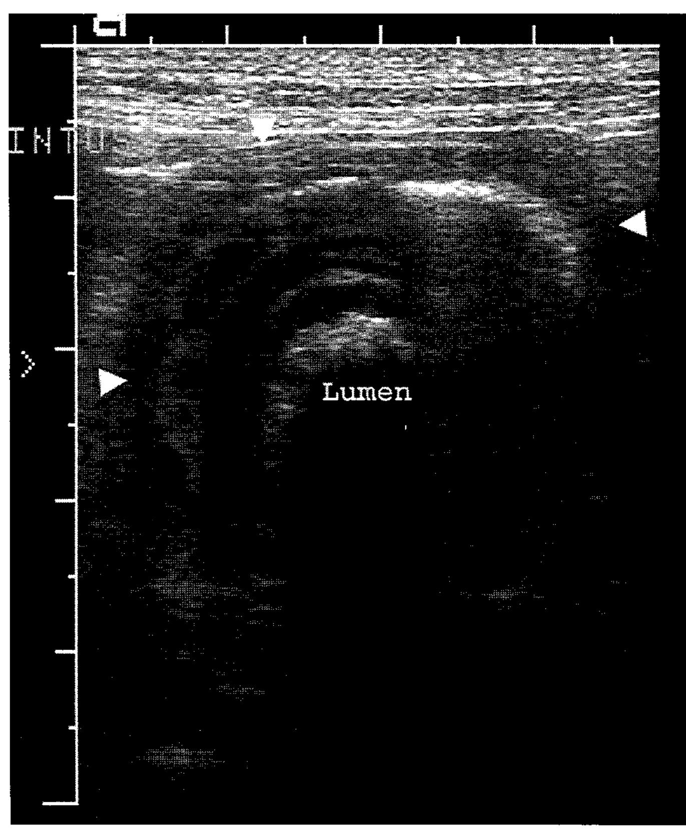

Fig 12. Transverse ultrasonographic image of a segment of small intestine in a dog with abdominal pain and vomiting. A tubular soft tissue structure could be plapated. An intussusception can be seen (see the text for detailed explanation).

Fig 13. Ultrasonographic image of a segment of fluid-filled distended small intestine due to ileus in a dog with abdominal pain. Poor peristalsis was noticed during the actual sonographic evaluation.

can also become a useful tool that can help in the treatment for pancreatic pseudocysts. Fine needle ultrasound-guided drainage has been reported as a successful technique to treat pancreatic pseudocysts in dogs. This technique is part of the so-called "interventional ultrasound." No complications have been reported.[24]

Gastrointestinal Tract

Gastritis, gastric ulcers, and gastric dilation-volvulus are common causes of acute abdomen.[1,2] Radiography is the best imaging technique to select for evaluation of gastric dilation-volvulus. The sonographic features of gastritis and gastric ulcers have been already reported by others.[25,26] It is common to identify the layers of the stomach wall in dogs with inflammatory disease affecting the stomach.[27] However, the layer identification is not possible in case of infiltrative neoplasia or severe gastritis.[25,26,28] Ulcerated areas can be identified using ultrasonography, and appear as a mucosal defect or crater.[28] Ultrasound has also been used to diagnose gastritis in dogs.[25-27] Normal thickness of the stomach wall evaluated on ultrasound ranges from 3 to 5 mm.[27] The stomach wall thickness may range from 9 to 15 mm in canine patient with gastritis.[25] Uremic gastritis is a fairly common finding in dogs with renal insufficiency. The sonographic findings include thickening of the wall of the stomach and rugal folds, and mineralization of the gastric mucosa as evidence by hyperechoic lines at the level of the gastric mucosa.[26] The visualization of a hyperechoic curvilinear line with strong shadowing artifact is common sonographic pattern produced by attenuating foreign bodies. Foreign bodies in the stomach are easy to identify during the sonographic examination if there is fluid accumulation, commonly observed if a partial obstruction is present. Some foreign bodies can partially transmit the ultrasound wave and others cannot, depending on the physical characteristics of the foreign body.[27,29]

Obstruction of the small intestine is one of the most common causes of acute abdomen due to gastrointestinal tract disease. Common causes of intestinal obstruction include foreign body, linear foreign body, and intussusception.[25,27] Sonographic features for the diagnosis of intestinal intussusception are multiple concentric rings or a multilayered soft tissue structure with an apparent target lesion caused by fluid accumulation within the intestinal lumen (Fig 12).[25,27] Inflammatory bowel disease is also a cause of acute abdomen.[1,2] Inflammatory bowel disease is characterized by evidence of generalized paralytic ileus, fluid accumulation within the lumen of the affected intestinal segment, and an increase in intestinal wall thickness with preservation of the normal layers (Fig 13).[25,27] The same concepts mentioned above for foreign bodies in the stomach also apply for the small intestine. Linear foreign bodies can be identified as echogenic lines within the lumen of the small intestine, with a plicated appearance of the affected small intestinal segment. Enlarged mesenteric lymph nodes may also be observed because of reactive hyperplasia.[25,27] Intestinal lymphangiectasia may also produce clinical signs of acute abdomen. The radiographic and sonographic findings of this condition have been reported already. The ultrasonographic findings include abnormal thickening of the wall of the small intestine and stomach, increased echogenicity of the mesentery, a corrugated appearance of the small intestine, enlargement of the mesenteric lymph nodes, lack of visualization of the normal layers of the small intestine, and dilation of the segments of small intestine. Inflammation of the pancreas also may be observed.[30]

Urinary System

Ultrasonography is a useful tool that allows the visualization of the internal architecture of the renal parenchyma. This provides information on changes of the ultrasonographic anatomy of the kidneys.[31] The sonographic anatomy of the kidneys is somewhat complex, and the reader should consult other articles that offer a detailed description.[32-34] The most valuable aspect of ultrasonography is its ability to differentiate fluid-

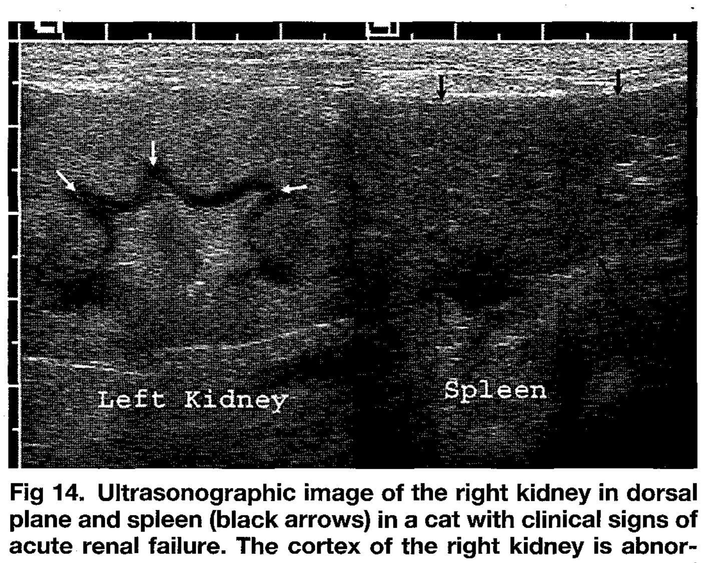

Fig 14. Ultrasonographic image of the right kidney in dorsal plane and spleen (black arrows) in a cat with clinical signs of acute renal failure. The cortex of the right kidney is abnormally hyperechoic compared to the splenic parenchyma and there is also poor corticomedullary differentiation. The renal diverticulae (white arrows) are dilated due to mild hydronephrosis.

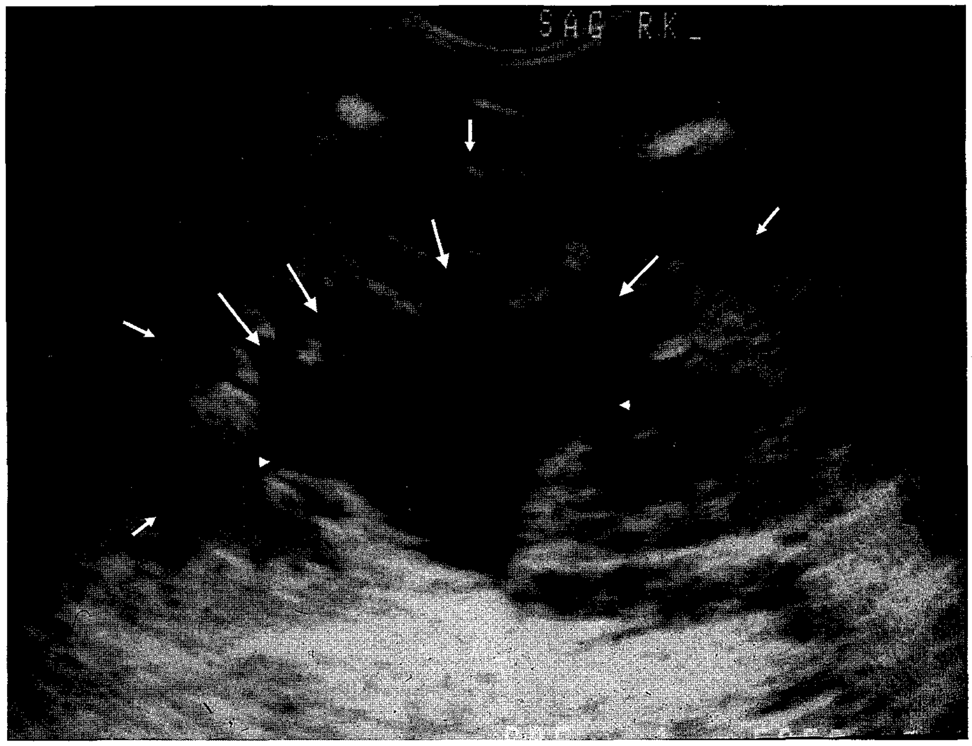

Fig 15. Ultrasonographic image of the right kidney in sagittal plane (short arrows). Dilatation of the renal pelvis (arrowheads) and renal diverticulae (long arrows) can be seen as evidence of hydronephrosis.

filled cavities (cysts, abscesses) from solid masses such as neoplasia.[35,36] Unfortunately, there are no specific ultrasonographic patterns for accurate diagnosis of renal disease.[31,37] Acute nephritis, glomerulonephritis, renal tubular necrosis caused by ethylene glycol toxicosis, renal calculi, acute pyelonephritis, acute hydronephrosis renal infarcts, hematomas, and abscesses are conditions referable to the kidneys that may produce clinical signs of acute abdomen.[1,2] A renal cortex that appears hyperechoic with poor corticomedullary differentiation is the most common finding on ultrasound in dogs with acute nephritis, glomerulonephritis, renal tubular necrosis, and pyogranulomatous nephritis in cats with feline infectious peritonitis (Fig 14).[36,37] Animals with glomerulonephropathies may have normal ultrasonographic findings.[35-37] Hyperechoic renal cortex and medulla (caused by deposition of calcium oxalate crystals) with a hypoechoic halo at the corticomedullary junction (caused by diminished deposition of calcium oxalate crystals) are common sonographic findings in animals with ethylene glycol toxicosis. Episodes of anuria have been found in dogs with visualization of the halo sign, which indicates a poor prognosis.[38] Either renal or ureteral calculi produce hyperechoic areas with acoustic shadowing.[31,35,36] A hyperechoic rim at the corticomedullary junction may be identified in dogs with hypercalcemia.[39,40] This finding is not pathognomonic for hypercalcemia, as a hyperechoic rim sign may also be seen in normal cats and dogs.[41] However, dogs with medullary rim sign with other concurrent ultrasonographic renal signs also commonly have renal disease.[41] Radiolucent calculi that are not detected by conventional radiography can be identified with an ultrasonographic examination. The acoustic shadowing produced by radiolucent calculi is weaker when compare with radiopaque calculi.[31]

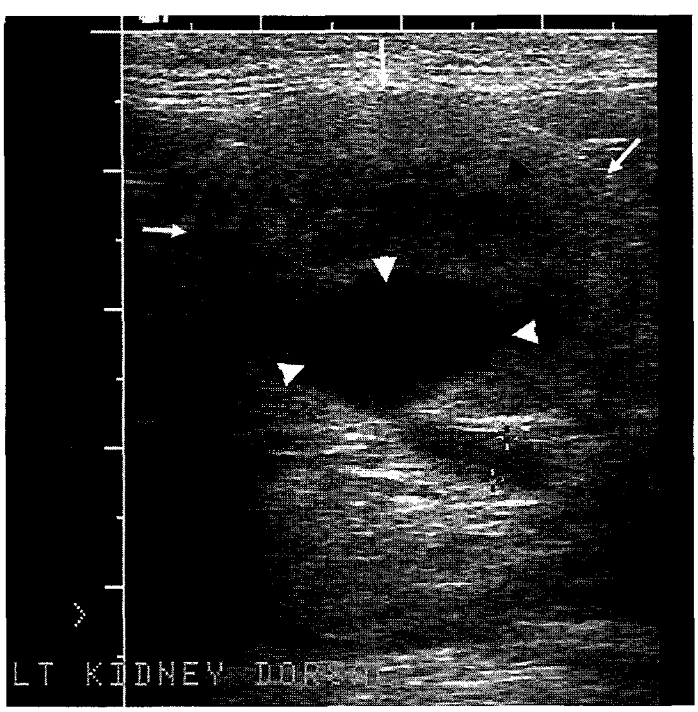

Fig 16. Dorsal ultrasonographic image of the left kidney (white arrows) in a cat with pyelonephritis. There is dilatation of the renal pelvis (white arrowheads) with irregular internal surface. The proximal ureter is mildly dilated (between cursors). There is marked poor corticomedullary differentiation (black arrowheads). Notice that there is no dilatation of the renal diverticulae (compare with kidney on figure 15).

Acute hydronephrosis is characterized by dilation of the renal pelvis, proximal ureter, and renal diverticulae (Fig 15). Ultrasound can detect whether renal or ureteral urolith are the cause of hydronephrosis. If no calculi are seen in the kidneys or ureter, the trigone area in the urinary bladder should be carefully evaluated to identify the potential cause of ureteral obstruction, such as transitional cell carcinoma, prostatic tumor extending to the trigone region.[31,42] Rhabdomyosarcoma at the level of the trigone of the urinary bladder causing severe hydro-

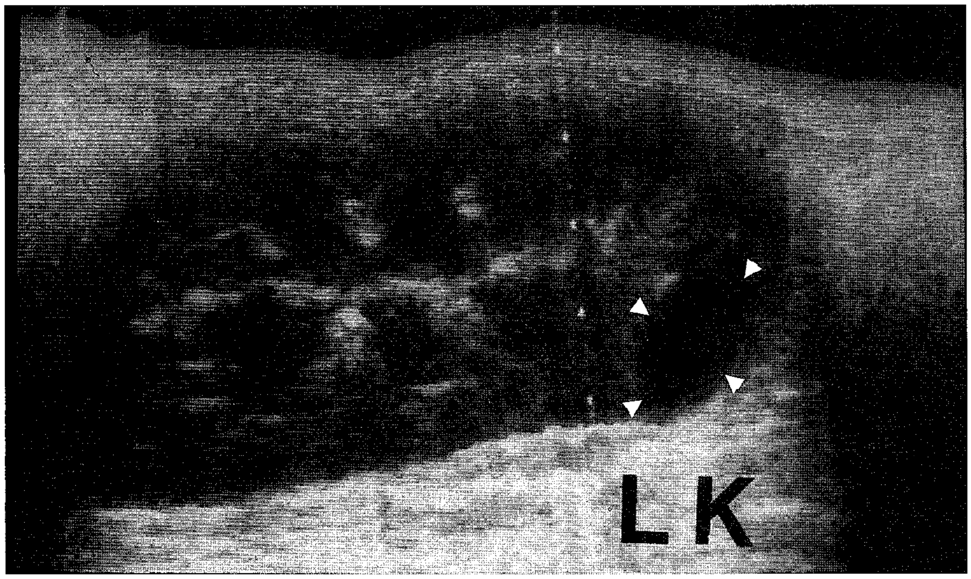

Fig 17. Sagittal plane ultrasonographic image of the left kidney with an anechoic ovoid structure in the caudal pole (arrowheads) due to an abscess.

nephrosis bilaterally in a 10-month-old German Shepard has been observed by the author. Similar ultrasonographic features of mild acute hydronephrosis are also present in pyelonephritis, so the differentiation between mild pyelonephritis and mild hydronephrosis using ultrasound may be difficult (Fig 16). In some cases, the content of the dilated renal pelvis in dogs with hydronephrosis may have high cellularity and cellular debris. Debris can be visualized as very small multifocal areas of mixed echogenicity within the renal pelvis. Additionally, increased echogenicity of the mucosal surface of the pelvis and/or proximal ureter, increased echogenicity of the renal cortex, hyperechoic areas in the medulla, or focal hypoechoic areas in the renal cortex have been found in dogs with experimentally induced pyelonephritis. The proximal ureter sometimes can be dilated in most of the cases, and sometimes a complete ureteral dilation can be seen. Poor corticomedullary differentiation, irregularly shaped pelvis, and diverticula also may be present.[31,43] Pyelectasia has been referred to as mild pelvic dilation without evidence of dilation of the diverticula or proximal ureter induced by diuresis. This normal condition should not be confused with mild hydronephrosis or pyelonephritis.[31] Renal infarcts are identified as focal triangularly shaped hyperechoic areas seen in the renal cortex. Renal abscesses are characterized by the presence of focal hypoechoic or anechoic lesions with hyperechoic foci if the fluid is very cellular (Figs 17 and 18). Through transmission artifact produced by abscesses may not be as strong as the through transmission produced by renal cysts, which are completely anechoic with smooth and thin walls.[35-37]

Sonographically, the urinary bladder is easily identified in the caudal abdomen as a well-circumscribed ovoid anechoic structure with a smoothly outlined wall. The inner and outer

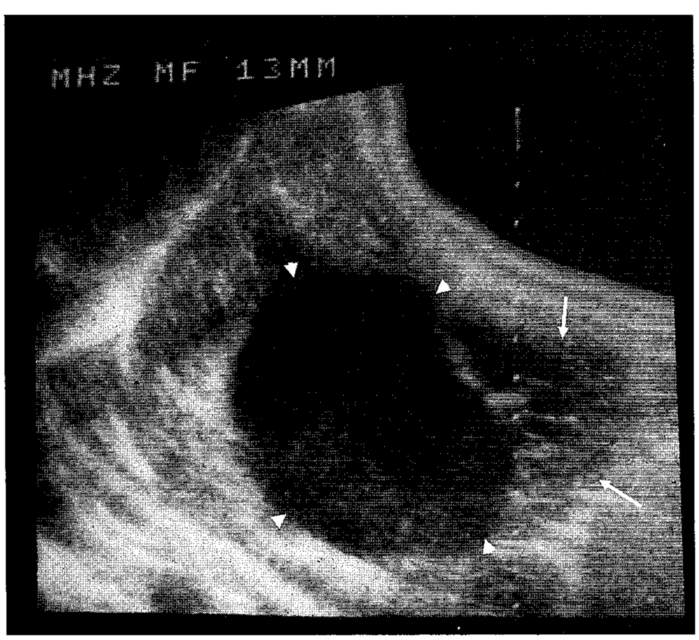

Fig 18. Sagittal plane sonographic image of the right kidney that shows a large hypoechoic well circumscribed structure in the mid to cranial aspect of the kidney (arrowheads). This is a renal abscess. Normal kidney parenchyma can be seen (arrows).

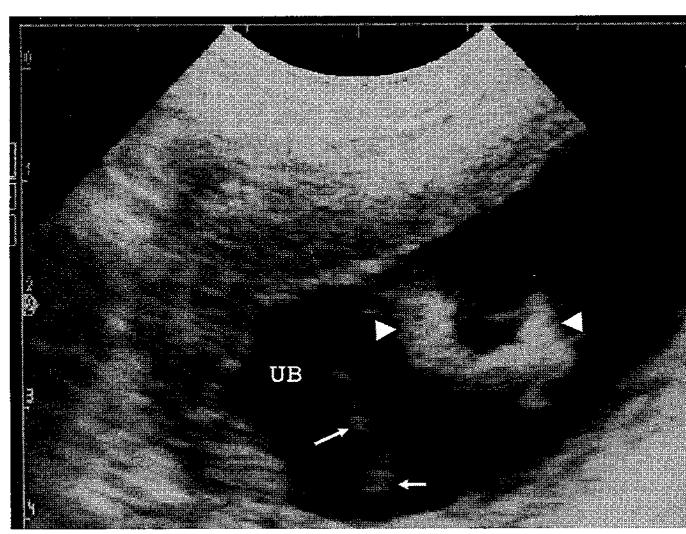

Fig 19. Sagittal plane ultrasonographic image of the urinary bladder in a dog with intraluminal hemorrhage due to severe trauma (hit by care) a few hours prior to the ultrasonographic examination. An irregular hyperechoic structure (arrowheads) and multiple hyperechoic foci (arrows) (blood clot formation) are seen in the bladder. Notice that shadowing artifact is not seen, which is a key to rule out bladder stones.

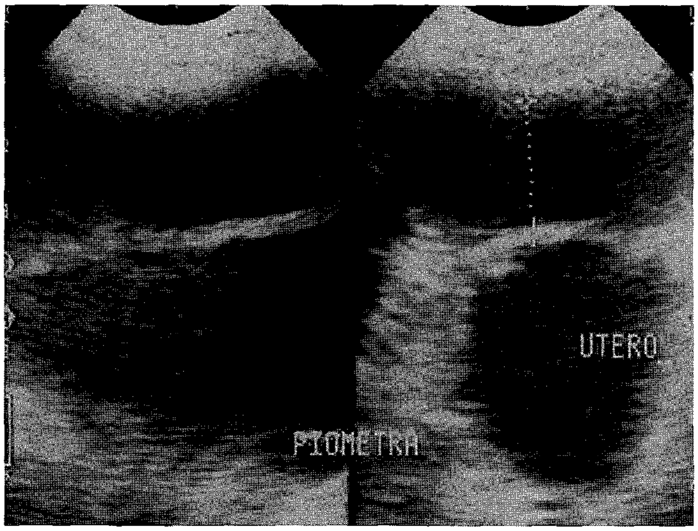

Fig 20. Ultrasonographic image of the uterine horns in a bitch with closed pyometra. See the text for detailed description.

aspects of the bladder can be visualized. No echogenic material should be seen within the urinary bladder. Directing the ultrasound beam on sagittal plane from the apex to the most caudal aspect of the bladder, the trigone area can be identified in the area in which the urinary bladder narrows. At that point, the most cranial aspect of the urethra can be observed in the area of the trigone. Low gain settings should be used to avoid intense echoes returning to the transducer, which can produce echogenic artifacts within the urinary bladder. This artifact may be interpreted as the presence of cellular debris or crystalluria.[31] If any of these conditions are suspected, the patient should be evaluated in standing position to evaluate changes in the position of the echogenic foci. Gentle agitation of the urinary bladder is another useful strategy to check for motion of the echogenic foci. High gain settings may also interfere with adequate evaluation of the urinary bladder wall. When measuring the thickness of the urinary bladder wall, the size of the bladder should be subjectively assessed.[31] Increased thickness of the bladder wall in an empty urinary bladder should not be misin-

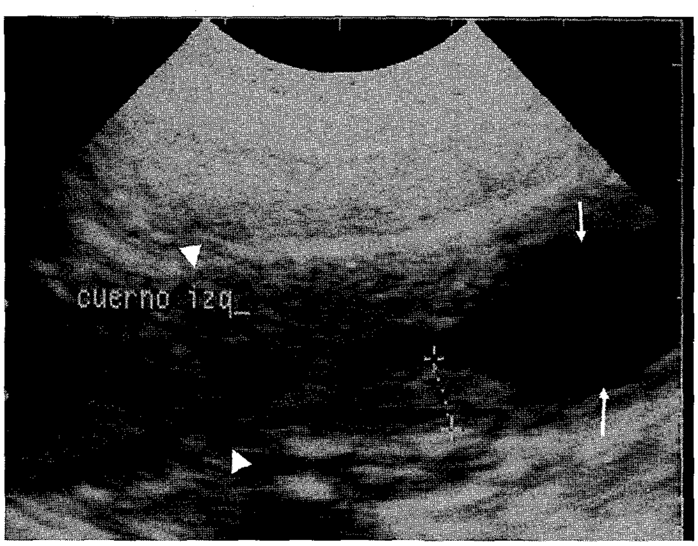

Fig 21. Ultrasonographic image of the left uterine horn in a bitch with opened pyometra. The uterine horn (arrowheads) contains anechoic fluid (arrows) and the mucosa is very thickened and irregular (between cursors) due to concurrent metritis.

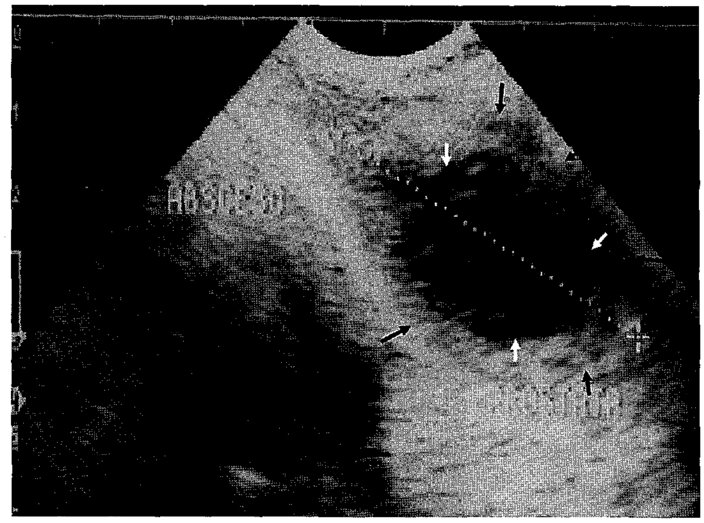

Fig 22. Sagittal plane ultrasonographic image of the prostate (black arrows) in a dog with tenesmus, dyschezia, and scrotal purulent discharge. The prostate is enlarged (between cursors) and has a central anechoic area with multiple small hypoechoic foci (white arrows). Although the differential diagnosis includes prostatic cyst and prostatic abscess based solely on the ultrasonographic findings, abscess was highly supected due to the presence of hypoechoic foci within the fluid-fileld structure. A prostatic abscess was confirmed during surgery.

terpreted as abnormal. Normal thickness of the bladder wall is approximately 1.0, 1.4, and 2.3 mm in diameter in the fully distended, moderately distended, and poorly distended bladder, respectively.[44] The wall of the bladder can be 1 mm thicker in heavy dogs when compared with light dogs. In cats, normal urinary bladder wall thickness has been reported to range from 1.3 to 1.7 mm.[31]

Fig 23. Ultrasonographic image of the retroperitoneal space caudal to the right kidney. A large hypoechoic structure (large arrows) (due to inspissated purulent material) with some anechoic areas, focal rounded hyperechoic areas (small arrows) (focal mineralization), and thick wall (arrowheads) can be seen. Pus was obtained on aspiration. A retroperitoneal abscess was found on surgery.

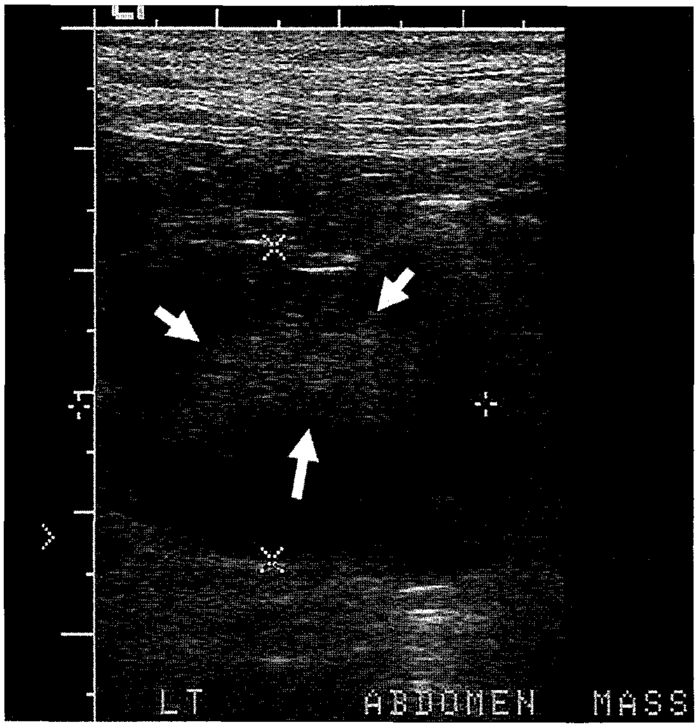

Fig 24. Ultrasonographic image of an abdominal hematoma due to spontaneous recent hemorrhage. A rounded well-defined anechoic structure (between cursors) with a focal hyperechoic central area (arrows) can be seen.

Radiolucent and radiopaque calculi are easily detected with ultrasound. In both cases, the calculi appear as hyperechoic areas with strong acoustic shadowing. The examiner should be aware that the colon usually lies adjacent to the urinary bladder and appears hyperechoic because of the presence of intraluminal gas. The colon often appears as a hyperechoic curved line and may be confused with large urinary calculi. Evaluating the dog in standing position, applying gentle agitation of the bladder with the transducer, and scanning the area in different planes are important to differentiate the colon from large urinary calculi. This maneuver is also important to differentiate free gas within the urinary bladder (either from previous catheterization or from the presence of gas-forming bacteria as a cause of cystitis). Irregular or a striated appearance of an echogenic mass lesion in the lumen of the bladder is a consistent sonographic finding for blood clots. The mass can be either attached to the urinary bladder wall or free within the bladder lumen. If the blood clot is adhered to the wall of the bladder, it may be difficult to differentiate it from an intraluminal mass.[31,45,46] The author has seen intraluminal hemorrhage caused by recent trauma (hit by car) as a very hyperechoic mass type lesion free within the lumen of the bladder in a dog (Fig 19). Thickening of the urinary bladder wall, mainly seen in the cranioventral aspect of the bladder, is a common finding in cases of cystitis. The thickening may be diffused involving the entire bladder wall. Polypoid formation and small multiple masses may also be present.[31,45] When evaluating for mural masses within the urinary bladder, the examiner may observe a smooth, slightly convex, focal, well-defined small mass-like structure just cranial to the trigone area. This finding has been explained as the visualization of a short portion of the intramural part of the ureter. This is not frequently observed, depending on normal variation of the degree of bladder distension in some dogs. In some instances, two mass effects may be visualized when scanning on transverse view. If color Doppler is available, it can sometimes demonstrate the jet effect of the urine entering the bladder.[47]

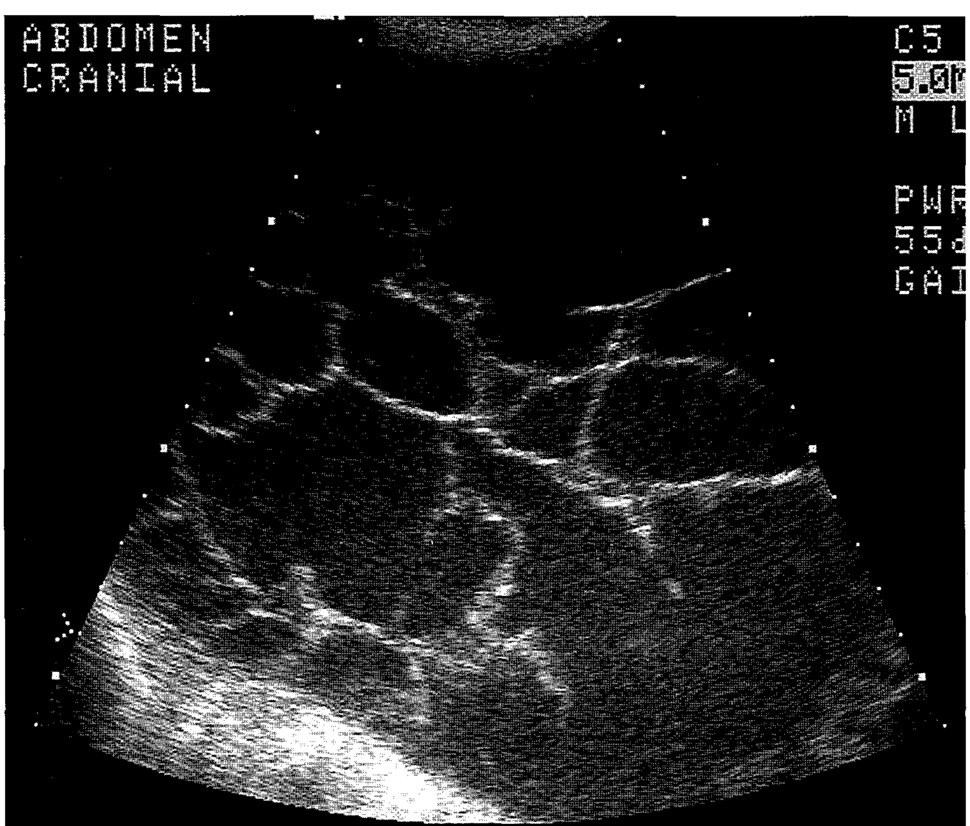

Fig 25. Ultrasonographic image of the abdomen in a dog with sclerosing peritonitis. Multiple linear hyperechoic structures are seen in the ascitic abdomen due to sclerotic transformation of the peritoneal layer and fibrin.

Reproductive System

Conditions of the reproductive system that can be diagnosed with ultrasound and also are associated with clinical signs of acute abdomen include pyometra and endometritis in the female and acute prostatitis and prostatic abscess in the male.[1,2]

The normal uterus may be difficult to visualize with ultrasound, mostly during metaestrus and anestrus. During proestrus and estrus, the body of the uterus can be seen sometimes as a hypoechoic tubular structure dorsal to the urinary bladder, and the left and right horns can be followed cranially as the transducer is moved.[48]

Pyometra is defined as the presence of purulent material within the lumen of the uterus because of exaggerated influence of progesterone on the endometrium. Pyometra is identified as an anechoic to hypoechoic tubular structure (depending on the amount of cellular debris present in the purulent material), which can be linear or convoluted. Through transmission artifact may be seen. The walls of the uterus are usually thin.[48,49] Unpublished data from a pilot research performed by the author at the Veterinary Policlinic, College of Veterinary Sciences, University of Zulia, Venezuela, on bitches with pyometra show some interesting findings. Twelve bitches were ultrasonographically evaluated after estrus because of clinical signs consistent with pyometra. Most of the patients were presented within 30 to 40 days after the onset of a heat cycle. Eight bitches had closed pyometra (without evidence of vaginal discharge), and the remaining four had open pyometra (with evidence of abnormal vaginal discharge). In bitches with closed pyometra, the uterus appeared as a tubular anechoic to hypoechoic, severely distended, convoluted structure (Fig 20). Two to three anechoic circular structures were also seen when scanning in transverse view. The uterine wall appeared mildly thickened in most of the patients. In bitches with open pyometra, the uterus appeared mildly enlarged with small amount of anechoic to hypoechoic fluid. Most commonly, the uterus appeared as a linear tubular structure. The uterine wall appeared very thickened and with a smooth outline (Fig 21). Interestingly, in one bitch, the uterus appeared as a hypoechoic linear structure without intraluminal fluid accumulation, but had anechoic cystic-like structures. This was observed on both sides of demid to caudal abdomen. Cystic endometrial hyperplasia was diagnosed. Cystic lesions containing purulent material were confirmed at surgery. Similar findings have been observed in a bitch examined at the VTH of Colorado State University. This form of presentation of pyometra can be called atypical pyometra. The diagnosis of pyometra was confirmed after surgery in all patients. The mildly distended uterus can be distinguished from an intestinal loop because of the absence of peristalsis in the uterus and no visualization of normal intestinal layers.[48-50] Endometritis can be identified on ultrasound as a mildly distended uterus that contains anechoic to hypoechoic fluid. The uterine wall is usually very thickened, and the mucosal lining is very irregular.[48]

The normal prostate is seen on sonographic evaluation as a hypoechoic bilobed (on transverse plane) or circular (on sagittal plane) structure located caudal to the urinary bladder in the intact male dog. In the castrated dog, the prostate is seen also caudal to the bladder as an ovoid elongated hypoechoic structure. In both cases, the normal echogenicity of the prostate is homogenous with well-defined, smooth margins. An enlarged prostate with diffusely or patchy hypoechoic areas throughout the prostatic parenchyma have been observed in dogs with acute bacterial prostatitis. The presence of cavitations in the prostate that may vary from anechoic to hypoechoic has been reported as a common finding in dogs with prostatic abscess (Fig 22). The level of echogenicity of the purulent material in the abscess depends on the amount of cellular debris. Reactive lymphadenopathy affecting the medial iliac lymph nodes may be present in both pathologic processes.[48,51,52]

Abdominal Cavity and Retroperitoneal Space

Conditions in the abdominal cavity that can produce clinical signs of acute abdomen include abscess formation, hematomas, and peritonitis. An abscess in the abdominal cavity or retroperitoneal space can be seen as a fluid-filled cavity with thick, irregular walls. Through transmission artifact may be seen. The sonographic characteristics of the fluid may be anechoic to hypoechoic, depending on the viscosity of the fluid. Hyperechoic internal multifoci may be present because of the presence of cellular debris (Fig 23). The presence of gas caused by gas-producing bacteria in the abscess may also produce hyperechoic areas with an irregular distribution. Abscesses also can have a very complex echotexture. Abscesses and granulomas have been reported in dogs as consequence of grass awn migration. The sonographic features of hematomas in the abdomen or retroperitoneal space are variable, and depending on the time that it is observed after its formation. Recently formed hematomas appear as irregular and ill-defined echogenic structures (Fig 24). As clot lysis and retraction occur, the hematoma takes on a more anechoic appearance.[53]

Ultrasound is exquisitely more sensitive than radiographs for detecting a small amount of peritoneal effusion.[54] The areas to be scanned to look for small amount of ascites are at the level of the apex of the urinary bladder and at the renal fossa of the liver between the right kidney and the caudate lobe of the liver. Small amount of fluid also may be detected around the gallbladder. Irregular and extremely hyperechoic to heteroechoic mesenteric fat is a common finding for peritonitis. This is commonly seen in dogs with severe acute pancreatitis.[53] Severe chronic peritonitis may predispose to sclerosing peritonitis. This implies thickening and histologic transformation of the peritoneal layer associated with transformation of fibrin into sclerotic tissue. This sclerotic tissue organizes in the abdomen, forming an encapsulated type mass lesion called "abdominal cocoon" or encapsulated ascites, and may be confused with an abdominal mass on palpation and also on radiographs. Segments of small intestine may become entrapped in the cocoon, which diminishes the peristalsis, giving the small intestine a corrugated appearance. Multiple hyperechoic linear structures interspersed within an anechoic area (the ascitic fluid) may be seen on ultrasound (Fig 25). The anechoic area is encapsulated by a very hyperechoic membrane.[55]

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